Memorandum

U.S. Department of Transportation
Federal Highway Administration

Subject: INFORMATION: International Pavement Technology France - FHWA-PD-96-022

Date: July 23, 1996

From: Director, Office of Engineering

Reply to Attn. of: HNG-45

To: Regional Administrators
Federal Lands Highway Program Administrator

Attached is a copy of the subject report prepared by Mr. John M. Becker, formerly of the Pavement Division, summarizing his 8-month assignment to work with engineers from various agencies in France. An Executive Summary of the report is provided on pages iii-v.

The objective of this extended assignment was to work closely with engineers of the Directorate of Routes and other agencies in France (with a brief visit to Germany), in order to gain an understanding of the technical decisionmaking process utilized on the National Highway System related to the pavement design, construction, maintenance and performance evaluation, and how the demands of society and economic policy affect engineering decisions. From this assignment, an understanding was gained of the social and political environment under which the highway program in France developed, so as to better comprehend how and why their highway program works the way it does. Observations generated are discussed in the Executive Summary and recommendations made are listed on pages 105-108.

Three copies of this report are being furnished for your information. Two copies are being furnished directly to each division office. Additional copies of the report are available. If you have comments or questions, please contact Messrs. T. Paul Teng, John Hallin or Roger Larson of the Pavement Division at (202) 366-1324.

Gerald L. Eller

3 Attachments

ERRATA

International Pavement Technology - France -- Publication No. FHWA-PD-96-022

Please insert the attached Technical Report Documentation Page in your copy(ies) of this publication.

Technical Report Documentation Page

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Eight month assignment with engineers from the French Directorate of Routes in their Department of Public Works, Transportation and Tourism Agency and other highway agencies.

16. Abstract

The objective of this extended assignment was to work closely with engineers of the Directorate of Routes and other agencies in France, in order to gain and understanding of the technical decisionmaking pocess utilized on the national highway system related to pavemnt design, construction, maintenance and performance evaluation, and how the demands of society and economic policy affect pavement engineering decisions. Fran this assignment, an understanding was gained of the social and political environment under which the highway program in France developed, so as to better comprehend how and why their highway program works the way it does.

Recommendations developed for consideration by the U.S. highway community include: establish a focal point for collecting and disseminating pavement technology information to the public and private sector, establish a network of well-connected research and development laboratories to serve regional/national R&D implementation activities, monitor the standads being developed and adopted by the European Committee for Standardizaion and evaluate laboratory devices to determine whether they can be utilized in improving the quality of our pavements, evaluate innovative contracting procedures including alternate bids, facilitate the use of innovative asphalt mixes into the design procedure for flexible pavements, examine the viability of design catalogues for pavements (NCHRP project currently underway), examine the viability of utilizing maintenance catalogues and continually reevaluating the priority place on routine maintenance onthe NHS, use trapeziodal cross-sections for pavement structures evaluate the performance of CRCP reinforced with galvanized strips, and consider using the moderator format to facilitate technology transfer discussions.

The report concludes that opportunities for improving the way in which business is conducted should be sought out. As stewards of the National Highway System, we need to continuously work to better the condition of our nation's pavements.

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Pavement technology, asphalt, concrete, pavement design, testing, maintenance, construction, rehabilitation performance evaluation, innovatie contracting, warranties, and design catalogs.	No restrictions. This document is available to the publce through the National Technical information Service, Springfield, VA 22161

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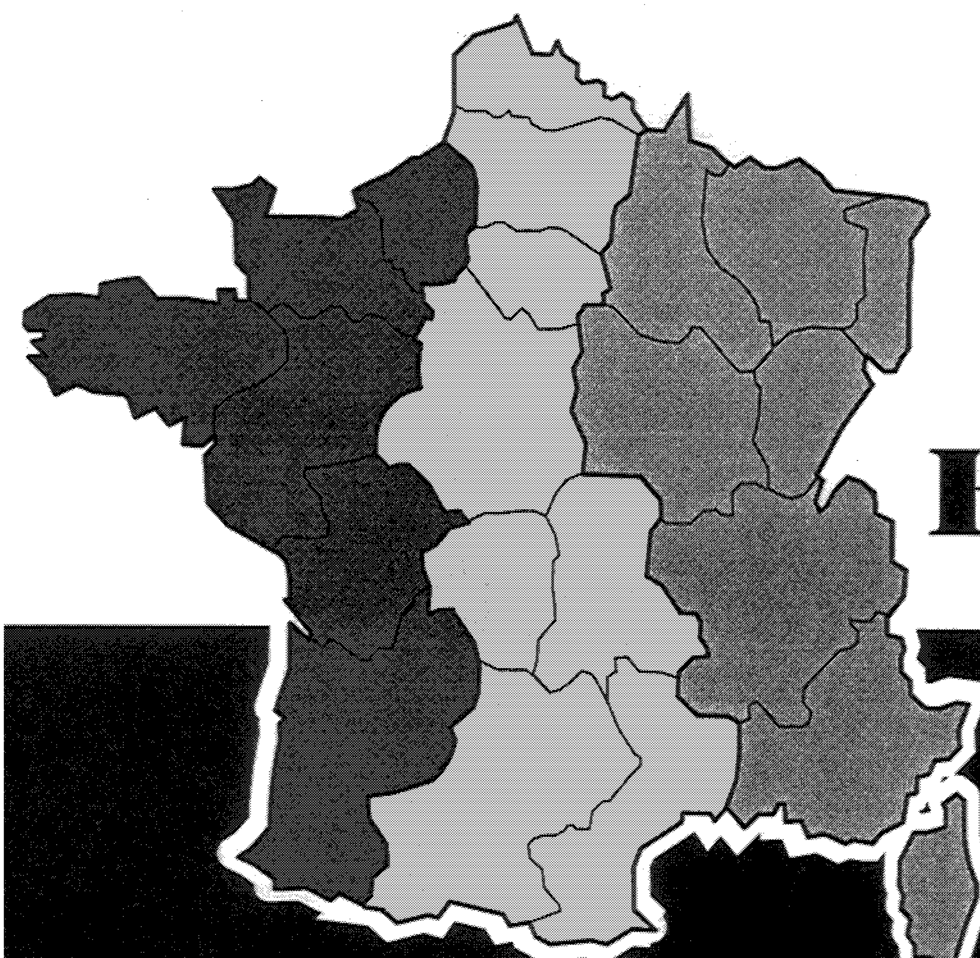

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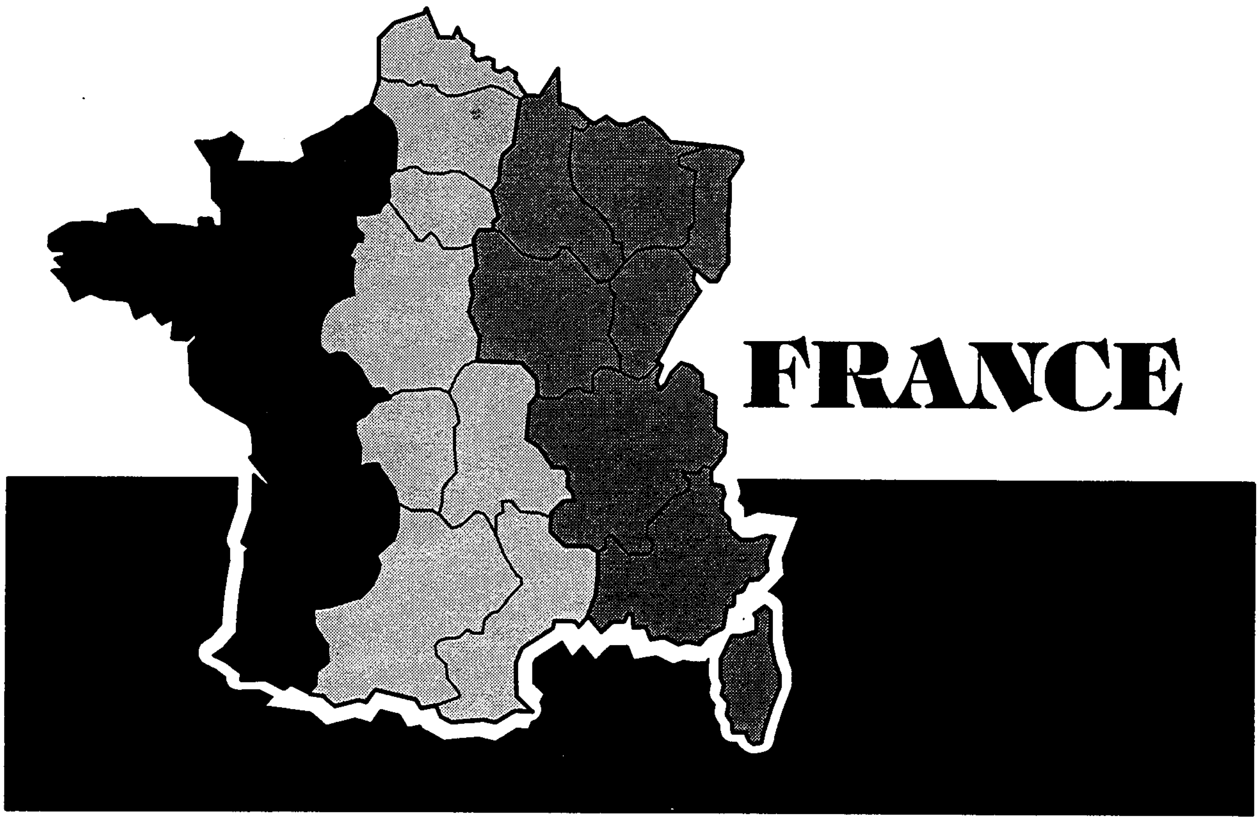

US Department of Transportation
Federal Highway Administration

i. Acknowledgements

This assignment was conducted by the Federal Highway Administration, Office of Engineering, Pavement Division, in consultation with the International Cooperation Division and the Executive Development Division. A sincere appreciation is extended to the many individuals from the Directorate of Routes in France, and their partners, who gave their valuable time and effort to discuss, at my level of proficiency of their language, issues related to their highway program.

The efforts of Mr. Roger M. Larson of the Pavement Division in the diligent review of this report are dutifully noted. The guidance provided by Mr. Donald G. Symmes of the International Cooperation Division in the review and critique of this report is appreciated. Suggestions and remarks developed by Messrs. Bradley O. Hibbs of the Pavement Division, Max G. Grogg of Region One, and Frank M. Rich of Region Eight, in the review of this report are also acknowledged. Finally, it would be remiss not to mention the roles of Messrs. Louis M. Papet and John P. Hallin of the Pavement Division, who proposed that this assignment be undertaken, with a sincere desire to see that we understand the practices and procedures from abroad which have the potential for improving the quality of our pavements here at home.

ii. Disclaimer

iii. Executive Summary

Over the past several years, teams of engineers and managers representing the Federal Highway Administration (FHWA), several State Highway Agencies (SHAs) including the American Association of State Highway and Transportation Officials (AASHTO), and industry have undertaken tours to, respectively, review and evaluate asphalt pavement technologies and construction techniques in six European countries, review and evaluate rigid pavement design and construction practices in five European countries, and to review and learn about contracting practices and procedures in four European countries. Observations and impressions gained during these tours were presented in reports titled the European Asphalt Study Tour (EAST) report, the United States Tour of European Concrete Highways (US TECH), and the Contract Administration Techniques for Quality Enhancement Study Tour (CATQEST).

From these tours and several follow-up tours, recommendations have been successfully demonstrated and/or implemented in the United States. For example, the Stone Mastic Asphalt (SMA) technique was demonstrated in several states, and a concrete pavement section using European design and construction techniques was demonstrated in Michigan.

Because of the interest generated from these tours and reviews, the Federal Highway Administration agreed to undertake an extended assignment for one individual to work closely with engineers of a European country, namely France. The objective of this extended assignment was to work closely with engineers of the Directorate of Routes and other agencies in France, in order to gain an understanding of the technical decision making process utilized on the national highway system related to pavement design, construction, maintenance and performance evaluation, and how the demands of society and economic policy affect pavement engineering decisions. From this assignment, an understanding was gained of the social and political environment under which the highway program in France developed, so as to better comprehend how and why their highway program works the way it does.

Recommendations are discussed in detail on page 105 of this report. Listed below are some of the observations generated during this extended assignment.

> *The highway program in France operates as a very close-knit community. The majority of engineers who work for and with the Directorate of Routes are graduate engineers from the Ecole des Ponts et Chaussées in Paris. These engineers exhibit a camaraderie in their working relationships throughout their careers, whether it is with the Directorate of Routes, with concessionaires, or with private contractors, materials suppliers, and equipment manufacturers. The involvement of the public and private sectors is intertwined in many of their activities, and it is difficult at times to distinguish between the two. It is a unique demonstration of partnering.*

> *A high priority is placed on maintenance of pavements. During the post World War II period in France, maintenance was limited to only repairing distressed pavements.*

Preventive maintenance was non-existent, and as a consequence of the harsh 1962-63 winter, National Routes in France were closed to traffic for an average of 30 days during the spring thaw, resulting in a disastrous impact to their economy. This catastrophe resulted in their highway system receiving the attention of all of France and leaving an impressionable mark on the French highway community to this day. From this catastrophe, aggressive actions were undertaken to repair these pavements and to undertake a program which resulted in approximately 80% of the kilometers of National Routes being structurally overlaid.

The Autoroutes are a generally new part of the French highway network. In 1970, there were only 1,120 km of Autoroutes open to traffic. In 1980, approximately 3,980 km of toll Autoroutes (and 720 km of non-toll Autoroutes) were open to traffic. From 1970 to 1993, an average of approximately 236 km of Autoroutes a year have been placed in-service. Because longer sections of Autoroutes are more conducive to toll revenue generation and collection, it was not uncommon to encounter 20 to 30 km long earthwork projects, and 30 to 50 km paving projects. As of 1993, approximately 5,830 km of Autoroutes were open to traffic. The majority of the Autoroutes are managed by the one private and seven mixed-economy concessionaires. These concessionaires operate similar to a utility company; the Minister of Finance sets the amount that the concessionaires can collect in toll revenues and sets the limits on expenditures for new construction and for maintenance, in consultation with the Directorate of Routes.

Approximately eighty percent of highway construction, rehabilitation, and heavy maintenance activities in France are performed by eight large, vertically integrated, enterprises/contractors. These enterprises/contractors have regional offices throughout parts or all of France. Some of these enterprises are also subsidiaries of larger conglomerates, including banking, shipping, communications, and other interests which are sometimes partially owned by the national government. The shift in emphasis from smaller, National or Departmental Route type projects from 1949 to 1970 to the longer Autoroute projects contributed to the incorporation of smaller construction firms into the larger enterprises; the larger enterprises being better able of handling 20 to 50 km long projects.

Innovative and well-established procedures allow for the use of alternate bids and proprietary products. On National Route projects (which are predominately bituminous-surfaced), bid packages often require price submittals for either two or three equivalent alternate designs (i.e., bituminous-surfaced pavements with different types of base structures), although alternate bids are not used in pavement-type selection of asphalt versus concrete. When properly documented and supported by laboratory testing and/or national (advisory technique) committee recommendations, reductions in layer thicknesses (of no more than 10 to 20 mm) are allowed on National or Departmental Routes, but not on the Autoroute projects managed by the mixed-economy concessionaires. The mixed-economy concessionaires do allow for the use of innovative or proprietary materials, *and use warranties (of three to five years) exclusively for the (proprietary) surface layer. Because warranties do not apply to underlying layers, and because of the unique relationship between the owner and the contracting sector, there is debate as to whether warranties are a major force behind the quality of the entire pavement structure.*

Design catalogues are used for all types of flexible and rigid pavements. These catalogues are stratified, by pavement surface and base types (in France, there are 23 combinations), into three or four truck load categories, and three or four platform (or soil support) categories. Catalogues are developed (based on local conditions or other factors) by the pavement experts, incorporating good design practices (e.g., drainage layers, crack relief layers, widened lanes, positive load transfer devices), and are easily used by practitioners at all levels within the highway community. The selection of appropriate layer thicknesses is, of course, facilitated by the use of design catalogues. Generally, the design periods for new pavements are 15 years for flexible pavements, 20 years for semi-rigid type pavements, and 25 years for rigid pavements.

Field visits of active projects revealed that Autoroute projects managed by the mixed-economy concessionaires were staffed and controlled to a degree similar to that found on Interstate projects in the United States. Departmental Route projects were virtually absent of any inspectors and quality control was performed by the contractor and with submission of certificates and test results. Because Autoroute construction projects are controlled much more closely than are National Route or Departmental Route projects, there is less expected variability or risks associated with projects built by the concessionaires. Consequently, for the same level of traffic and platform support, the concessionaire design catalogues reflect thinner layers than the Directorate of Routes catalogue used for National Route or Departmental Route projects.

Plastic rutting was rarely encountered in France. Ninety-six percent of the mixed-economy managed Autoroute pavements had rutting levels of no more than seven millimeters. The Directorate of Routes believes that the use of the gyratory compactor, in conjunction with the rut-tester has improved the quality of their pavements. It was also indicated that other testing devices, including the micro-deval device (essentially a wet abrasion test), has had a positive impact on the quality of aggregates used in their pavements.

Despite cultural differences, highway programs from other nations merit further study. Many technical issues transcend political boundaries, and a major factor why other nations are able to use our technology to their advantage is simply because they can communicate with us; they understand our language. To close this gap, we should continue fostering partnerships and exchanges between our engineers and engineers from abroad, to tap into the positive experiences gained elsewhere, to utilize research and development accomplishments from abroad, and to always promote practices and procedures which have the potential for improving the quality of our pavements.

iv. Table of Contents

I. Background

In 1990, a team of engineers and managers representing the Federal Highway Administration (FHWA), several State Highway Agencies (SHAs), and industry undertook a two week tour of Europe to review and evaluate asphalt pavement technologies and construction techniques in six European countries. The European Asphalt Study Tour (EAST) report [1], published in 1991, is a summary of observations and impressions gained during this tour. In 1992, a team of engineers and managers representing the FHWA, several SHAs, and industry undertook a similar tour to study rigid pavements in five European countries. The report on the United States Tour of European Concrete Highways (US TECH) [2] was presented at the Transportation Research Board (TRB) annual meetings in 1993. A third tour was undertaken by the FHWA, several SHAs, and industry during the fall of 1993 to review contracting procedures in four European countries; the report on the Contract Administration Techniques for Quality Enhancement Study Tour (CATQEST) [3] was presented at the TRB annual meetings in 1994.

Although an unfortunate consequence of the forementioned tours was that some observations were misinterpreted by members of the highway community as well as by the press, [4] many positive recommendations have been successfully demonstrated and/or implemented as a direct result of the EAST and US TECH tours and from respective follow-up tours. For example, the Stone Mastic Asphalt (SMA) technique was demonstrated in several states, [5] and a concrete pavement section using European design and construction techniques were demonstrated in Michigan [6].

This eight-month assignment was undertaken following the EAST and US TECH tours, in order to learn about the technical decision making processes related to highways and to pavements, and how the demands of society and economic policy affect those decisions. This assignment was not undertaken for the purpose of comparing their highway program to ours, although our highway program is sometimes used as a reference in this report to highlight similarities and/or differences. It is vitally important to remember that the environment under which their highway program developed and now operates, historically and politically, is different from ours. It helps to understand why their system works for them.

Why was France selected as the country in which an extended assignment was to be undertaken? Of the countries visited by the EAST and US TECH participants (see Table 1.1), only France and Germany were visited by both. Because of their demonstrated experience in both flexible and rigid pavement technology, an extended assignment involving both countries was envisioned. However, issues confronted Germany as a result of the reunification of their eastern states into their federal republic; consequently the FHWA pursued arrangements for an extended assignment exclusively with the Directorate of Routes in France. The very active involvement of the French Directorate of Routes in international highway activities, most notably in PIARC, was viewed as a plus.

The earliest chapters of many highway programs in the United States progressed with inspiration and with knowledge gained elsewhere. A young scientist named Logan Waller Page gained valuable experience in the scientific methods of highway construction from the French Laboratory of Bridges and Roads, using this experience to establish several state transportation laboratories in the United States. Always insisting on improving road technology in the United States, Page later served fourteen years as the third Highway Administrator of what is now the Federal Highway Administration.[7, 8]

As with other innovative and/or progressive highway programs, the highway program in France continues to merit study; particular features (and experiences) could be of use or interest to one's own State highway agency. Items of interest which may have a potential for improving the quality and/or efficiency of our highways are discussed in this report. Many of these items are no more than a different approach used to conduct business. These specific items, which are all discussed in more detail on page 105 of this report, include the following:

Administrative

- Establishing a national focal point for technology and technical services.
- Networking laboratories to efficiently perform national research efforts.
- Continuing international scanning activities and technology exchange.

Process and Product Recommendations

- Monitoring and evaluating European test methods and specifications, including:
  - Equipment used to reduce rutting in flexible pavements.
  - Equipment used to control the quality of aggregates.
- Implementing innovative contracting procedures that encourage innovation by the private sector without compromising the competitive bidding process.
  - Evaluating the performance of modified bituminous mixtures.
- Developing local design catalogues for the proposed National Highway System.
- Reevaluating and/or elevating priorities on maintenance.
  - Developing local catalogues for maintenance for the proposed NHS.
- Evaluating promising design, construction and rehabilitation techniques
  - Utilization of trapezoidal cross-sections.
  - Monitoring the performance of CRCP using galvanized steel.
- Utilizing the moderator format during technical conferences for promoting technology to management.

Within the field of highway and pavement engineering, technology has not been a phenomena transferred only from the old world to the new. The Europeans have kept abreast of highway engineering activities in the United States, and have used our technology to their advantage in improving their state of the practice in highway engineering. Many of the European nations have utilized portions of the AASHTO Guide for the Design of Pavement Structures[9] in their development of their design catalogues. Europeans have sent many of their engineers to the United States to learn how we design and construct our pavements. The Europeans have long been active participants in international congresses and conferences, including the Transportation Research Board Annual Meetings. The Europeans, in both the public and the private sector, have also been participating in the Strategic Highway Research Program (SHRP), including hosting annual SHRP Conferences, and they are active participants of the Long-Term Pavement Performance (LTPP) project, as discussed in Section 13.5 of this report. It was remarkable to encounter the many individuals who have worked in the United States gaining positive and valuable experiences in the highway engineering profession.

§

Table 1.0. International Pavement Technology Tours/Scanning Missions. [1, 2, 3, 5, 6]

Nation	EAST	US TECH	CATQEST
Austria		X *	X
Belgium		X	
Denmark	X		
France	X	X	X
Germany	X *	X *	X
Great Britain	X		
Italy	X		
Netherlands		X	
Spain			X
Sweden	X *		

* Follow-up tours of the EAST and US TECH tours.

II. Objective

The objective of this assignment was to work closely with engineers of the Directorate of Routes and other agencies in France to gain an understanding of the technical decision making process utilized on the national highway system related to pavement design, construction, maintenance and performance evaluation, and how the demands of society and economic policy affect pavement engineering decisions. The general approach outlined to meet these objectives included:

1. Working closely with officials of the Directorate of Routes and the mixed-economy concessionaires responsible for pavement engineering. This included the following:
   - Development of standards
   - Pavement structural design
   - Selection of pavement type
   - Consideration of design alternatives
   - Monitoring and evaluation of pavement performance
   - Selection of maintenance and rehabilitation strategies

2. Becoming familiar with pavement related contract administration procedures for projects administered by the Department and Road Concessions, including:
   - Methods for selecting contractors
   - Contract monitoring/management methods by owner
   - Visits of active pavement construction projects

3. Becoming familiar with the pavement research program.

4. Visiting neighboring countries to review active construction projects and to discuss design and construction procedures.

This report includes a summary of findings, observations, discussions, and general comments formulated during eight months in 1993 with the Directorate of Routes.

The first three months were spent on a variety of visits, informal presentations and related activities of the Directorate of Routes organization, with activities located mainly in the Paris metropolitan area. The last five months were spent on activities with the Directorate of Routes predominately in western France, and on follow-up visits. The actual manner in which the assignment was carried out was through a series of visits lasting anywhere from one day to two weeks. These many short visits allowed for discussions with individuals who shared their (sometimes) frank and diverse opinions on various facets of their highway program.

Activities were structured in order to establish preliminary contacts with the various offices that comprise the French highway community. This included the technical services office known as the Service d'Etudes Techniques des Routes et Autoroutes (SETRA), the central laboratory known as the Laboratoire Central des Ponts et Chaussées (LCPC), several regional laboratories known as Laboratoires Régionales des Ponts et Chaussées (LRPC), contractors, and Autoroute concessionaires who manage the Autoroutes. Several national and international conferences were also attended.

III. Historical Background

There have been many influences over the millennia which have shaped France. The environs of several islands situated in the middle of the Seine River were inhabited over six-thousand years ago by the Parisii, a prehistoric Celtic tribe and ancestors of the Gauls. Four-thousand years later, the Romans conquered and began exerting a tremendous influence on the culture of the Gauls. Germanic invaders, most dominantly the Franks, but also others, were absorbed into the culture which, with the expulsion of the English and the incorporation of Normandie, Bretagne, and Provence, led to the formation of France. Although demographically negligible, there is much which continues to live on from the days of the Romans. The Roman culture continues to thrive in France, foremost in their romantic, latin language. The Roman influence continues in other ways, as remnants of their ancient infrastructure reminds us of their past presence and dominance in much of Europe. [10, 11]

The Romans were the first road builders in Europe, and their network of approximately 86,000 km of major roads created much of what is today modern Europe. [2] These Roman roads served all of Europe for centuries, some serving France until the time of Napoléon Bonaparte. Traces of these Roman roads are still visible, and the alignment of many Departmental and Communal Routes follow the alignment of these ancient roads. [12]

Road-building became recognized as a profession requiring application of scientific principles in the latter part of the eighteenth century. During this time, when France was still a monarchy, a roads and bridges administration gradually developed, headed by a body of specialized engineers trained at the Ecole des Ponts et Chaussées (Roads and Bridges School), which was established in 1747. [13] This school is still today responsible for educating most of the engineers who work for and with the Directorate of Routes in France.

A pioneer in the field of pavement engineering was Pierre Marie Jerome Trésaguet, named French Inspector General of Roads in 1775 by King Louis XVI. Trésaguet was one of the first engineers, but certainly not the last, who recognized the need for continuous maintenance of highways. To this day, maintenance continues to receive the attention and commitment of top management throughout the Directorate of Routes. Trésaguet also introduced the concept of relatively thin road surfaces, as opposed to the massive structures built by the Romans, relying on the underlying subsurface to support pavement loads. [14]

Another engineer renowned for his impact on pavement engineering in the 1880's was Bousinesq. His theory on elastic solids and elastic-layer systems is the origin of flexible pavement mechanistic design from which the Burmister theory of elastic multi-layered systems evolved. This is the fundamental backbone of the pavement design principles in use in France. [15]

In the 1950's, while the United States was designing and constructing the National System of Interstate Highways, France was undertaking the task of reconstructing the infrastructure damaged or destroyed during the liberation of western Europe. This effort of rebuilding the infrastructure put a heavy demand on materials, manpower, and finances, and partially explains why there was virtually no system of limited access facilities in existence in France until recently. Some of their most senior and distinguished highway engineers began their engineering careers during the post-war reconstruction efforts.

During the 1960's, it was a catastrophe, brought forth by nature, that resulted in their highway system receiving the attention of all of France and leaving an impressionable mark on the French highway community. To this day, experienced highway engineers in France point to 1962-1963 as a benchmark year from which their highway program evolved. Funding for maintenance during the post-war period was limited to repairing distressed pavements; preventive maintenance was non-existent, and as a consequence of the 1962-63 winter, National Routes were closed to traffic for an average of 30 days during the spring thaw, resulting in a disastrous economic impact. A study completed in 1967 concluded that 67% of the pavements on the National Route system were inadequate to handle current traffic, and that 33% were anticipated to fail rapidly. A program was commenced to resurface all National Routes, providing adequate thickness on their pavements to handle future traffic and to circumvent road closures due to spring thaw. This program ultimately resulted in approximately 80 percent of all National Routes being structurally overlaid. [16]

Today, the highway program in France operates in a very close-knit community. The majority of engineers who work for and with the Directorate of Routes are graduate engineers from the Ecole des Ponts et Chaussées in Paris. These engineers exhibit a camaraderie in their working relationships throughout their careers, whether it is with the Directorate of Routes, with concessionaires, or with private contractors, materials suppliers, and equipment manufacturers. The involvement of the public and private sectors is intertwined in many of their activities, so that it is difficult at times to distinguish between the two. It is a unique demonstration of partnering.

IV. General Overview

France is the largest nation in the European Union (EU) with a land mass of 551,000 square kilometers. It is smaller than Texas but larger than California, and its' population of approximately 57 million is slightly more than the combined population of those two states. Although the climate in France varies considerably with the topography, it is generally temperate, similar to that found in California. Other similarities exist between France and California; undowelled plain jointed concrete pavements (sometimes referred as the "californiennes") have been constructed in France since the 1970's. Not coincidentally, because of their similar soils and climate, both California and France are world renowned for their fine wines. Table 4.1 [1, 2, 17] includes some of the demographics of France.

France is administratively comprised of the following: [18]

> Twenty-two Regions composed of two to eight Departments each. The Regions own no routes but play a major role in the financing of National and Departmental Routes within their jurisdictions.
>
> Ninety-six Departments (similar to Counties), which play a major role in the financing of National Routes within their jurisdictions. Since 1984, there has been legislation in effect which has given more autonomy to the Departments; consequently, each Department is responsible for the design, construction, and maintenance of Departmental Routes. The degree of independence varies from Department to Department; in larger (more populous) Departments, there is a completely separate office that handles the Departmental Route program. In other Departments, the national government office continues to provide technical assistance to the Department.
>
> Over thirty-six thousand Communities, which are responsible for their own Communal Routes, and which sometimes play a role in the financing of Departmental or National Routes that affect them. In addition, many of the Communities are (public) part-owners of the seven mixed-economy concessionaires. There are 40 Communities with populations of 100,000 or more and in which 80 percent of the population resides.

Although there are several centers of high density population, France is a relatively rural agrarian nation, especially to the south and west of Paris. The population of France is concentrated around the city of Paris, which has a density of 20,500 persons per square kilometer; by comparison, the density of the city of Washington is only 3,000 persons per square kilometer! The Île-de-France region, which includes Paris, comprises 2 percent of the total land area and 19 percent of the total population of France. The population density of France varies significantly between the 22 political Regions, as is seen in Table 4.2, [19] placing unique demands on the transportation network. The population density of France equals that of Pennsylvania.

In Roman times, it was said that all roads led to Rome. In France, the same can still be said about Paris. Even to this day, it is very difficult, if not impossible, to drive through France on the Autoroute System without driving through the Paris metropolitan area. As approximately 235 km of Autoroute are added on to their system each year, this has begun to change. [17]

Although the population of metropolitan Paris has remained steady, in part because of immigration, there continues to be a gradual migration of the population from metropolitan Paris to other urban areas in France, including Lyon, Marseille, Strasbourg, Nantes, Bordeaux, Toulouse, Rouen, and Lille. [20] Although these urban areas have grown, they have remained relatively compact, because of a desire of residents to utilize public transportation, and, more importantly, because of the excellent public transportation system which serves them. This is not to say that the automobile is not an important transportation mode. A gradual increase in the number of vehicles owned, in conjunction with the migration of the population to the urban areas located throughout the country, has put a demand on the need for a well connected system of Autoroute highways.

As a result of this emerging Autoroute System, there has been an increase in the overall percentage of commerce transported on highways, from 69 percent in 1980 to 76 percent in 1988 as compared to other modes of transport. [17]

Table 4.1. Various Demographical Statistics. [1, 2, 17]

Item	United States	California	France
Population	245 000 000	28 000 000	57 000 000
Total Land Area (1 000 square kilometers)	9 400	411	551
Main and National Routes (kilometers)	651 900 000	44 000	35 600
Vehicles per 1 000 inhabitants	583	590	412
Main and National Routes/Population Density (kilometers/1000 inhabitants)	2.7	1.6	0.6
Main and National Routes/Land Area Density (kilometer/square kilometer)	0.5	0.6	1.5
Fatality Rate (deaths per 100 000 000 vehicle-kilometer)	1.5	1.6	3.0
Auto Expense (% of personal spending)	6	n/a	3
Total Tax Receipts as % of GNP	29.2	n/a	45.6

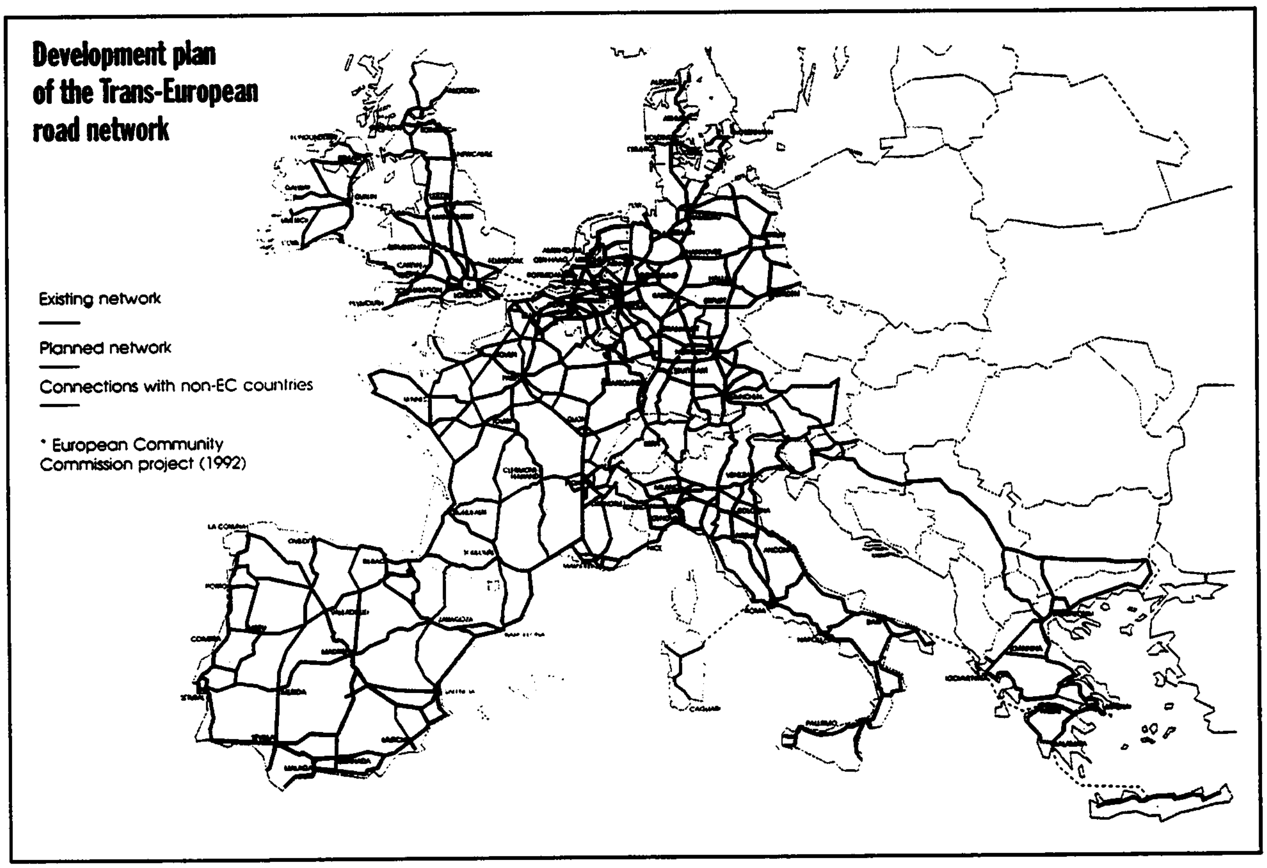

Figure 4.1. The proposed European Motorway Network. [17]

Table 4.2. Population Densities in Europe and the United States.[1, 19]

Region /Principal City in France	People /km²
Alsace /Strasbourg	196
Aquitane /Bordeaux	67
Auvergne /Clermont	51
Bourgogne /Dijon	51
Bretagne /Rennes	103
Centre /Orléans	60
Champagne-Ardenne /Châlons-sur-Marne	53
Corse /Ajaccio	29
Franche-Comté /Besançon	68
Île-de-France /Paris	883
Languedoc-Roussillon /Montpellier	77
Limousin /Limoges	43
Lorraine /Metz	98
Midi-Pyrénées /Toulouse	53
Nord-Pas-De-Calais /Lille	319
Basse-Normandie /Caen	79
Haute-Normandie /Rouen	141
Pays de la Loire /Nantes	95
Picardie /Amiens	93
Poitou-Charentes /Poitiers	62
Provence Alpes-Côte d'Azur /Marseille	135
Rhône-Alpes /Lyon	122

United States	People /km²
California	74
Connecticut	264
Illinois	80
Indiana	60
Maryland	188
Massachusetts	301
New Hampshire	48
New Jersey	401
New York	149
North Carolina	53
Pennsylvania	102
Rhode Island	369
Texas	25
United States (excluding Alaska)	32

European Union	
Austria	90
Belgium	318
France	102
Germany	219
Netherlands	349
Spain	77

V. The Directorate of Routes

The Department of Public Works, Transportation and Tourism, is the agency with the overall responsibility for the national infrastructure administration. Within this agency, the Directorate of Routes is responsible for the highway infrastructure. The Directorate of Routes formulates policy and procedures for the upgrading and maintaining of the existing National Routes network and they provide control of the Autoroute concessionaires. The headquarters of this administration is located west of Paris at the Grand Arch.

The engineering field offices of the Directorate of Routes are stratified into three horizontal levels of hierarchy, all under the control of the central office. There are 96 Direction Departementale de l'Equipement (DDE) offices, 17 Laboratoires Régionales des Ponts et Chaussées (LRPC), and 7 Centres d'Etudes Techniques de l'Equipement (CETE) which are primarily responsible for the National Routes. These offices also provide engineering services and materials testing, and work very closely with the Autoroute concessionaires, with the 96 Departments on their respective Departmental Routes, and with 36,500 communities on Communal Routes. There are also small staffs employed by the twenty-two Direction Régionale de l'Equipement (DRE) offices which participate administratively in the financing of highway projects. There are a total of 42,000 individuals employed by the DDE, DRE, and CETE offices across France. [17]

Table 5.1 [21] shows the network of offices responsible for providing highway engineering services and financing of public facilities in France. Whether by design or by accident, this horizontally structured network appears to have lent itself to professionals who are knowledgeable of the issues, and aware of the strengths and capabilities of the other offices with which they interact. Individuals working in one laboratory or one engineering office must routinely interact with several other laboratories and/or engineering offices. This also provides them flexibility in order to better provide the services requested or needed within their highway program. Professionals within the Directorate of Routes organization work well together to uphold and/or improve the state of the practice of highway engineering.

5.1. Direction Departementale de l'Equipement (DDE)

Within each department, a DDE office is responsible for design, construction and maintenance of the National Routes within its' departmental jurisdiction; the DDE works directly for the national government. Some DDE offices continue to assist and/or exclusively provide engineering services for the local Department on their Departmental Route program. Responsibility for the Departmental Routes projects (e.g., project selection, contractor selection), rests with the local political officials.

5.2. Direction Régionale de l'Equipement (DRE)

For each of the twenty-two regions, there is a DRE office that is responsible for developing master plans for financing under National-Regional development contracts, highway construction and maintenance of the National Routes within each regional jurisdiction. Each DRE works for the national government.

5.3. Centres d'Etudes Techniques de l'Equipement (CETE)

There are seven CETE offices in France, which are regional technical support offices. These offices are responsible for providing technical assistance, guidance, and expertise to their respective DDE offices; they also work very closely with the SETRA. These offices also provide oversight and consistency across Department borders within their respective jurisdictions. A typical CETE staff of 600 includes 100 engineers or advanced technicians. [22] Each CETE works for the national government.

5.4. Laboratories

There are seventeen LRPC or regional laboratories located throughout France which serve both the CETE and DDE staffs on project level quality assurance materials testing. Although the LRPC facilities work for the national government, the CETE facilities exercise some managerial control over the LRCP facilities. LRPC staffs also serve the LCPC or central laboratory (which has facilities in Paris and Bouguenais) on research work of national importance.

The LCPC is a world renowned research facility, performing both applied research as well as pure scientific research. The LCPC, consisting of two facilities, employs 560 individuals, 380 in Bouguenais (near Nantes) and 180 in Paris. Of these, 220 are engineers or scientists, and 230 are technicians. There are four sections which handle research activities related to pavements, and some of the specific topics being investigated are included in this report beginning on page 87. The annual budget for the LCPC is 230 million french francs (F_r), or $40 million. [22]

All of the seventeen LRPC regional laboratories are equipped to handle routine, project level materials testing and evaluation for the DDEs and the concessionaires. Non-routine type testing is sometimes performed exclusively at one facility. For example, the LRPC in Anger is the only LRPC that is equipped with the fatigue testing device used to evaluate experimental or proprietary asphalt mixes. National research related activities are also conducted by the LRPC facilities in concert with the LCPC. There are 2,070 people employed by the seventeen LRPC facilities, or 120 per LRPC. [21, 23]

Another facility associated with the laboratories is the Centre d'Etudes et de Construction de Prototypes (CECP), with facilities in Anger and in Rouen. The CECP is the facility that develops all Matériel Laboratoire des Ponts et Chaussées (MLPC) prototype and production-line testing equipment. The Directorate of Routes, all contractors in France, and other foreign governments and businesses use MLPC equipment.

The major laboratories/technical centers in France also include the Station d'Essais de Matériels Routiers (SEMR) in Blois. The SEMR is an impressive road equipment & plant test facility that has been in operation for 25 years. The Directorate of Routes believes that the public sector (not to mention the private sector) benefit from the studies undertaken by this facility, because it has enhanced and improved equipment which is used to construct pavements. Public and privately funded research studies are also conducted, and finally, this facility also conducts certification efforts of contractor owned equipment (e.g., materials hoppers, bitumen pumps and meters, spray bars, chip spreaders) to ensure that such equipment is capable of performing the intended work; this information is also utilized by the Directorate of Routes and the concessionaires in reviewing the contractor's quality control program. The annual amount contracted at the SEMR facility is approximately F_r 6,900,000 or $1,200,000, of which three quarters is research related and one quarter equipment certification related. The SEMR staff of twenty-two includes five engineers. [24]

The Directorate of Routes or wholly owned subsidiaries of the concessionaires perform the majority of transportation engineering services, consequently there is an absence of involvement of private engineering firms or private laboratories in the transportation program in France, with the exception of laboratories owned and operated by the major enterprises/contractors.

The enterprise/contractor laboratories, which include both central and regional laboratories, include an impressive array of testing equipment, which was often the same MLPC equipment found at the LCPC in Paris and Nantes as well as the LRPC regional laboratories. The enterprises/contractors use much of this equipment in quality control as well as in their development of new products. The Directorate of Routes believes that acceptance of new materials and products is facilitated because the contracting industry and the LCPC laboratories both utilize the same (MLPC) equipment and testing procedures, facilitating a dialogue between the public and private sector. [25] In addition, the contracting industry is represented by engineers and scientists, many who have earned post-graduate degrees in their respective fields. They stand equal to their counterparts representing the Directorate of Routes laboratories. Both private and public sector engineers also play active and prominent roles in international conventions and symposiums.

5.5. Service d'Etudes Techniques des Routes et Autoroutes (SETRA)

The Service d'Etudes Techniques des Routes et Autoroutes (SETRA), located in Bagneux, is the technical services center for the Directorate of Routes. It is indirectly involved in all phases of the highway program, from planning to operation of road and bridge facilities. It is responsible for developing design guides and manuals, recommended construction and maintenance practices and procedures, and for the development of an array of engineering tools including computer programs used by the highway community.

The SETRA staff of 390 is involved in providing technical expertise through project evaluations; they serve as instructors in national training courses, they are highly visible and they work very closely with the various field offices, including the DDE, LRCP, and CETE facilities. They are also visible in international highway-related activities, promoting their technical skills by serving on international task forces and by assisting foreign highway departments and other firms operating internationally. [18, 26]

5.6. Mission du Contrôle des Sociétiés Concessionaires (R/CA)

The Mission du Contrôle des Sociétiés Concessionaires (R/CA) is the Directorate of Routes office which is responsible for overseeing the Autoroute System. Discussions on their relationship with the concessionaires is discussed on page 27 of this report.

5.7. Current Highway and Employment Issues

Issues that currently face the French Directorate of Roads include: completion of their Autoroute System, including upgrading of many National Routes to controlled-access facilities, development and adoption of European Union (EU) standards (often called normalization or harmonization), development of pavement management systems including development and testing of their National Routes using their Image Qualite du Reseau National (IQRN) system, a shift in responsibility and control from the central office to the departments, and a shift of responsibility from the public sector to the private sector of the quality control and assurance of highway projects.

Personnel-related matters, including right-sizing, early retirements, and loss of institutional knowledge (confronting many highway agencies in the United States) have not become major issues *within* the French Directorate of Routes. Generally, morale within the Directorate of Routes as well as with their private sector counterparts appeared very high; there was a genuine pride exhibited by all employees in the work that they collectively undertake. Civil servants and private sector employees are both well respected by the whole community, who are viewed as positive contributors to the well-being of their society.

Although employment within the Directorate of Routes has remained stable, prospects within other sectors was not as certain. For example, discussions regarding the consolidation of the mixed-economy concessionaires (from seven down to four) had recently surfaced, causing concern among some about reductions-in-force. Outside of the highway community, unemployment throughout France has continued to hover at approximately 12 percent over the past few years, with one out of four (irrespective of completion of a college education) below the age of 25 being unemployed.

Table 5.1. Hierarchy of the Directorate of Routes Field Engineering Offices.[21]

DDE Offices	DRE Offices	LRPC Laboratories	CETE Offices
Ain, Ardèche, Drôme, Isère, Loire, Rhône, Savoie, Haute-Savoie	Rhône-Alpes	Lyon	Lyon
Côte-d'Or, Nièvre, Saône-et-Loire, Yonne	Bourgogne	Autun	
Doubs, Jura, Haute-Saône, Territoire-de-Belfort	Franche-Comte		
Allier, Cantal, Haute-Loire, Puy-de-Dôme	Auvergne	Clermont-Ferrand	
Corrèze, Creuse, Haute-Vienne	Limousin		Bordeaux
Ariège, Aveyron, Haute-Garonne, Gers, Lot, Hautes-Pyrénées, Tarn, Tarn-et-Garonne	Midi-Pyrénées	Toulouse	
Dordogne, Gironde, Landes, Lot-et-Garonne, Pyrénées-Atlantiques	Aquitane	Bordeaux	
Charente, Charente-Maritime	Poitou-Charentes		
Deux-Sèvres, Vienne		Anger	
Loire-Atlantique, Maine-et-Loire, Mayenne, Sarthe, Vendée	Pays de la Loire		Nantes
Côtes-d'Armor, Finistère, Ille-et-Vilaine, Morbihan	Bretagne	St-Brieuc	
Calvados, Manche, Orne	Basse-Normandie	Rouen	Rouen
Eure, Seine-Maritime	Haute-Normandie		
Cher, Eure-et-Loir, Indre, Indre-et-Loire, Loir-et-Cher, Loiret	Centre	Blois	
Nord, Pas-de-Calais	Nord-Pas-de-Calais	Lille	Lille
Aisne, Oise, Somme	Picardie	St-Quentin	
Ardennes, Marne	Champagne-Ardenne		Metz
Aube, Haute-Marne		Nancy	
Marthe-et-Moselle, Meuse, Moselle	Lorraine		
Vosges		Nancy/Strasbourg	
Bas-Rhin, Haut-Rhin	Alsace	Strasbourg	
Aude, Gard, Hérault, Lozère, Pyrénées-Orientales	Languedoc-Roussillon	Aix-en-Provence	Aix-en-Provence
Bouches-du Rhône, Var, Vaucluse	Provence-Alpes-Côte d'Azur		
Alpes-de-Hautes-Provence, Hautes-Alpes, Alpes-Maritime		Nice	
Corse du Sud, Haute-Corse	Corse		
Seine-Saint-Denis, Paris, Hautes-de-Seine, Val-de-Marne, Seine-et-Marne	Île-de-France	Melun	
Yvelines, Essonne, Val-d'Oise		Trappes	

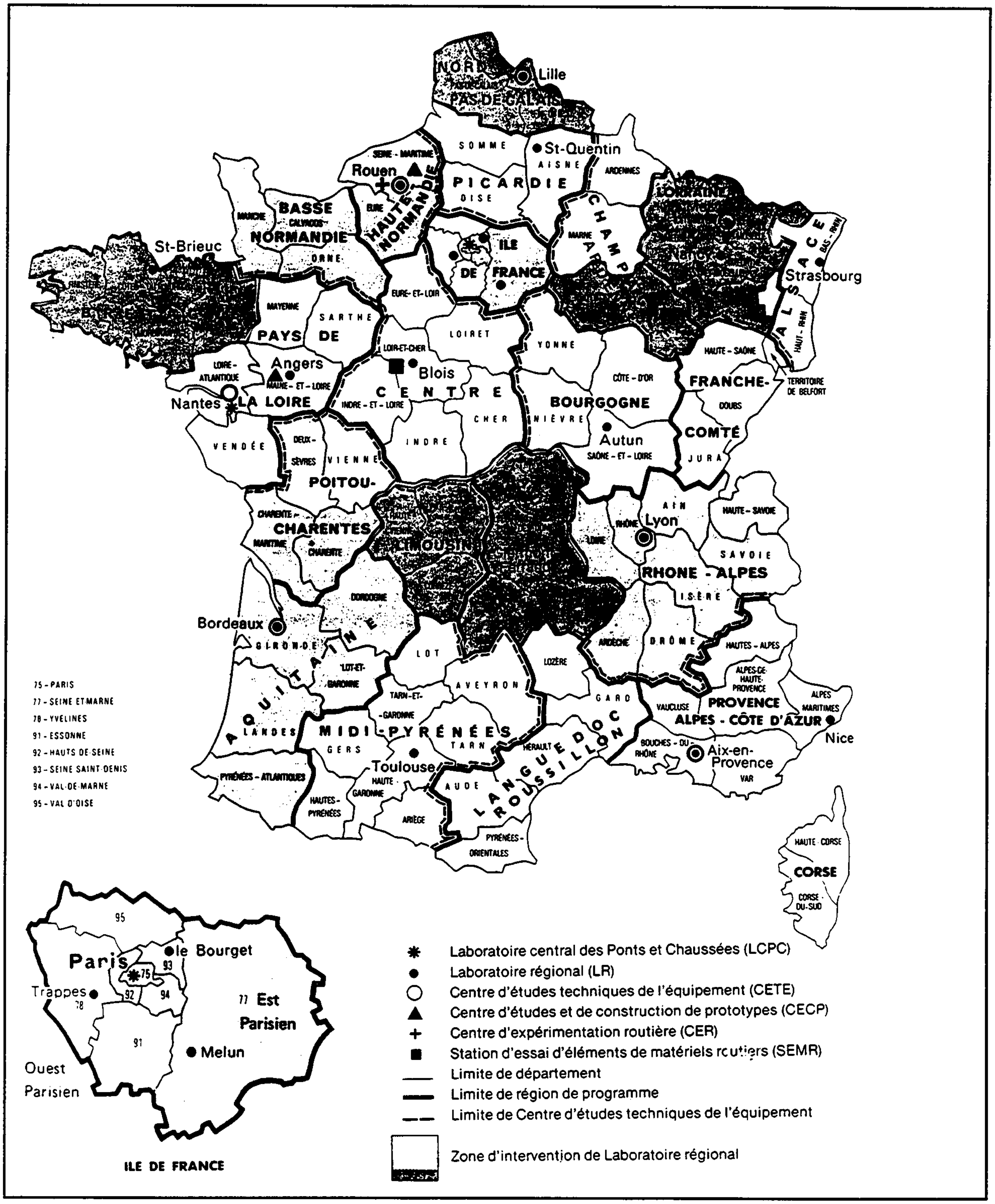

Figure 5.1. Location of the Directorate of Routes Field Offices.

VI. Highway Systems

There are currently 5,830 km of toll Autoroutes managed by seven semi-public and one private concessionaire under delegation of the Directorate of Routes, 810 km of non-toll Autoroutes, 29,000 km of National Routes, 354,000 km of Departmental Roads, and 526,000 km of Communal (city/village) Routes. [18, 27]

Supplementing the Autoroutes, there is a plan to improve/upgrade many divided four-lane National Routes to high type limited access facilities, mostly within existing rights-of-way, of routes which are logical connectors and/or extensions of the Autoroutes. These type routes (which currently number 1,540 km) are classified as Liaisons Assurant la Continuité du Réseau Autoroutier (LACRA). Other important connectors to the Autoroutes which will not necessarily be upgraded to limited access facilities but are recognized as important to the highway network include the Autres Grandes Liaisons d'Amenagement du Territoire (GLAT). Urban expressways which are not part of the Autoroute network because of poor geometrics, but which are of importance in carrying high traffic volumes through urban areas are classified as Voies Rapides Urbaines (VRU). Finally, the remainder of National Routes are classified as either Routes de Liaison (RL) or connectors, and Routes Ordinaires (RO) or secondary routes; many of the National Routes which parallel newer Autoroutes fall into these last two categories.

Between 1949 and 1969, National Routes numbered 83,000 km. This period also witnessed a five-fold increase in traffic volumes, and a stagnation of maintenance funding which only allowed for curative maintenance efforts, i.e., maintenance to specifically address a distress. After the winter shutdown of the road network during the winter of 1962-1963, over 55,000 km of National Routes were declassified to Departmental Routes, and an aggressive maintenance program was undertaken for the remaining 28,000 km of National Routes. [15]

The Autoroutes are a generally new part of the Highway System in France. In 1970, there were only 1,120 km of Autoroutes open to traffic. In 1980, approximately 3,980 km of toll Autoroutes and 720 km of non-toll Autoroutes were open to traffic. From 1970 to 1993, an average of approximately 236 km of Autoroutes have been opened annually to traffic in that period. [17] In addition, 1,042 km of 2x2 (two lanes in each direction) Autoroutes have been widened to 2x3 or 2x4 facilities since 1973. From 1991 to 1992 alone, 367 km of 2x2 Autoroutes were widened to 2x3 or 2x4 facilities.

The ultimate plan (for the year 2000+) is for a limited access network of 12,120 km, comprised of 9,540 km of (toll and non-toll) Autoroutes, and the complete conversion and upgrading of all 2,580 km of major connector routes to high-type LACRA facilities. [15]

The classification by categories of National Routes is used in prioritizing other work. These functional categories are used by the central government, for example, to preliminarily determine, based on square meters of surface, the maintenance funding levels allocated to the Departments. [27]

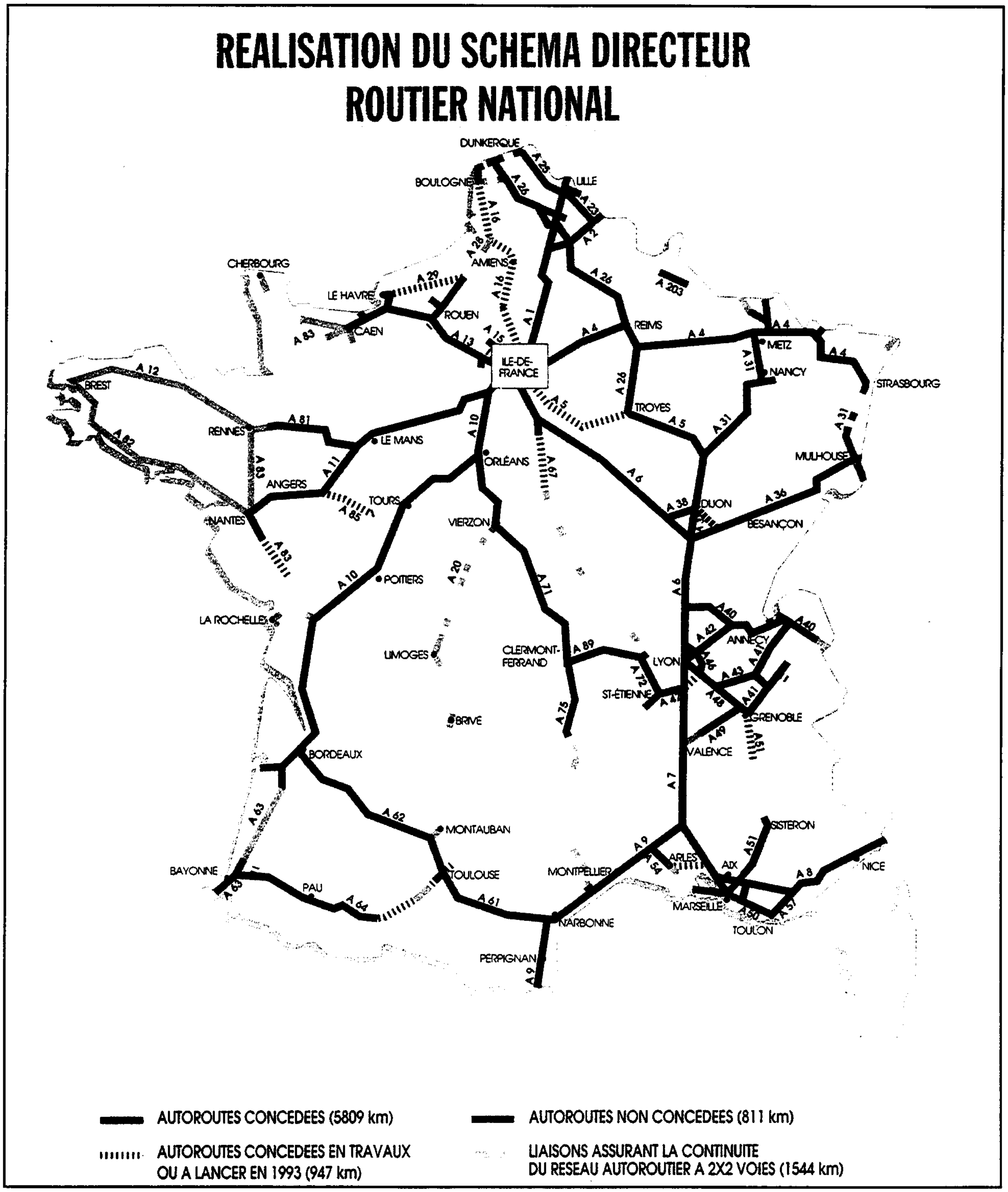

Figure 6.1. Autoroutes (toll and free), and the Major Connectors Open to Traffic or Under Construction. Source: Direction des Routes, France, 1993.

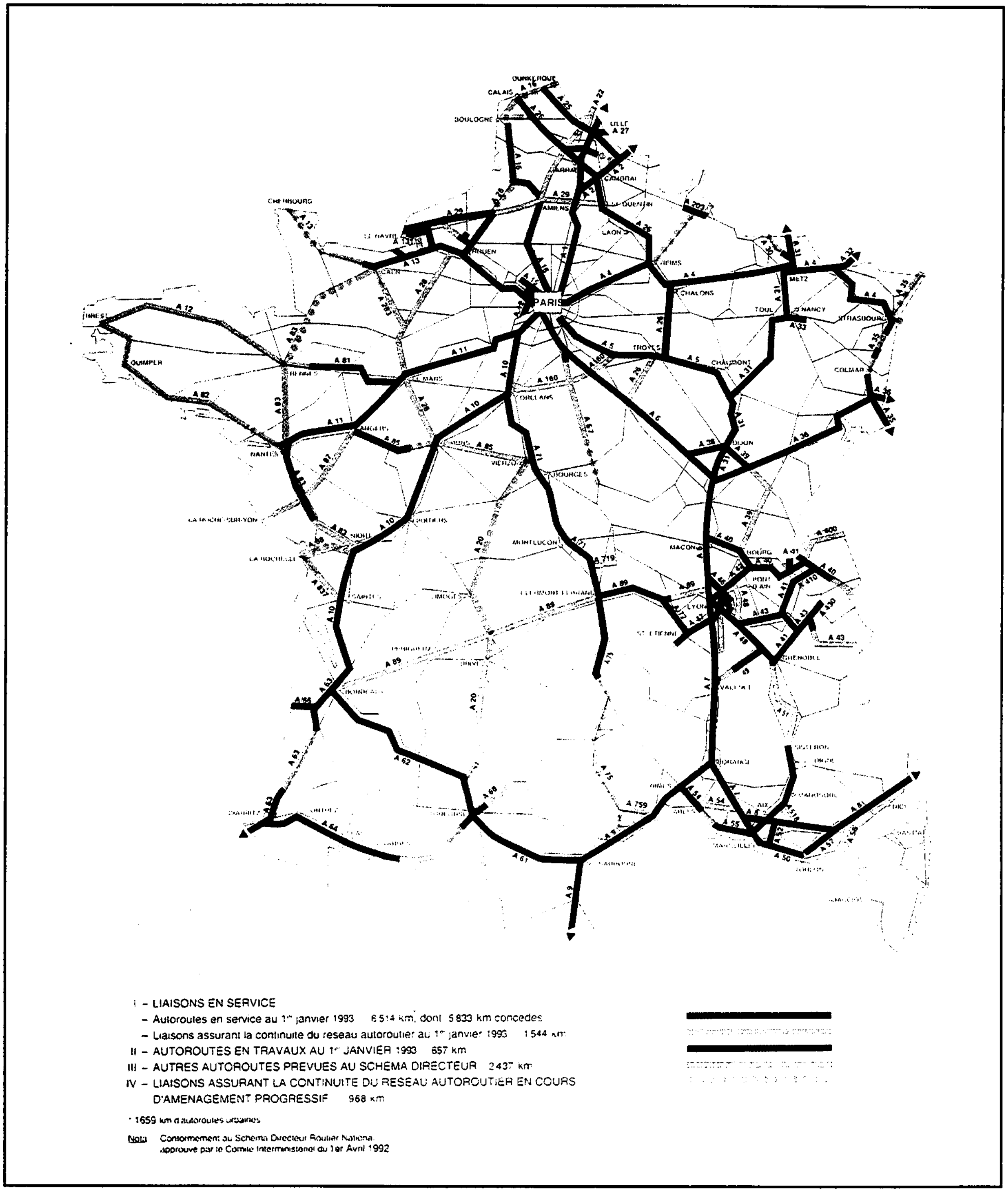

Figure 6.2. The Proposed Autoroute and Major Connector Network. Source: Direction des Routes, France, 1993.

Table 6.1. Classification of National Highways in France.[18, 27]

Classification	Existing (& Proposed) km	Average Daily Traffic
Autoroutes Toll	5 830 (8 730)	21 000
Autoroutes Free	810	45 000
National Routes		9 000
VRU	850	
LACRA	1 540 (2 580)	
GLAT	4 400	
RL (Connector Routes)	11 700	
RO (Secondary Routes)	9 700	
Departmental Routes	354 000	1 300
Communal Routes	526 000	150

VII. Financing

There are no dedicated taxes which are used exclusively for highways. Unlike in the United States, where users fees (such as taxes on fuel) are deposited directly into the Highway Trust Fund for use exclusively on highway system needs, revenues obtained from highway sources (motor fuel taxes, vehicle taxes) in France are collected and are included in a general pool which includes all other central-government generated taxes. The Minister of Finance distributes funds out of the pooled funds and distributes the funds to the Minister of Public Works, Transportation & Tourism to use for design, construction, maintenance, and management of the highway system. Although it was indicated that approximately half of the funds collected from transportation sources are returned for transportation uses, the amount varies considerably from year to year, making long range planning of highway funding very challenging. [15]

Taxes on fuel are much higher than those in the United States. The cost of a liter of fuel ranges from F_r 5 to F_r 6 ($1.00 to $1.25) per liter, or four times the cost typically encountered in the United States. In addition, all services and all items purchased or sold in France, which includes all highway contracts, include the Value Added Tax (TVA) of 18.6%. This helps to explain one reason why the average costs for products and services were generally higher than those encountered in the United States.

Funds budgeted by the National Government for the Directorate of Routes program, and funds expended by the Directorate of Routes are shown in Table 7.1. This does not include the budget of the concessionaires who manage the Autoroute System.

As can be seen in Table 7.1, the amount budgeted for pavement strengthening decreased by 31.1 percent over the previous year. This category, which includes the coordinated reinforcing or overlay program commenced after the impacts of the 1962-1963 winter were realized, is being phased out. All pavement strengthening will be handled either in the pavement maintenance program or in the pavement reconstruction program. [15]

Budgeting for the Autoroutes is also handled by the Secretary of Finance and is separate from the Directorate of Routes budget for National Routes. In 1992, total receipts from toll revenues and other related tolls reached F_r 20.5 billion, or $3.57 billion. [17] For every F_r 100 of toll revenues collected, 60 percent was budgeted for the amortization of loans used to finance the system, 32 percent was budgeted for maintenance and new construction, and 8 percent was used to pay for local taxes. [17] Consequently, the maintenance and construction budget for the concessionaires was approximately $1.14 billion in 1993.

Table 7.1. Road Budget for the Directorate of Routes.[17]

	Amount Budgeted, 1993 Million F_r /$US Million	Change from 1992 (Percent)	Percent of Program	Amount Allocated 1993 Million F_r
Pavement Maintenance	2 311.80 / 402.05	1.4	26.2	2 274.90
Pavement Strengthening	151.50 / 26.35	(31.1)	1.7	194.40
Bridge Upgrading	230.60 / 40.10	0.0	2.6	210.00
Construction/Reconstruction *	6 099.46 / 1 060.77	6.4	69.1	5 893.89
Autoroute Liaison Studies	30.00 / 5.22	0.0	0.4	30.00
Total	8 823.36 / 1 534.50	3.8	100.0	8 603.19

* Includes State-Region Contracts

VIII. Autoroute Concessionaires

The Autoroute System first evolved by law in 1955, with five semi-public companies, called concessionaires, performing all management services (project development, highway design, contract administration, maintenance, toll collection, system inventory, etc.) for the Directorate of Routes through 1969. In 1970, concessions were granted to private companies. It was envisioned that those concessionaires would remain as fully private entities. However, the escalating price of asphalt during the 1973 oil crisis resulted in increased costs for constructing Autoroutes. Compounding this, reduced private travel through 1985 reduced toll revenues. Three of the four private concessionaires existing at that time bore heavy debts and were not able to meet expenses. These private concessionaires were partially nationalized and reorganized with the existing semi-public concessionaires; one concessionaire had sufficient kilometerage in service by 1973, allowing it to continue operations to this day. In 1987, a capital stock endowment lent financial support to the mixed-economy concessionaires and with toll revenue obtained from in-service Autoroutes, public funds were no longer directly used to fund the Autoroute system.[28, 29]

Today, there are seven mixed-economy concessionaires responsible for managing their respective section of the Autoroute. These are Société des Autoroutes Rhône-Alpes (AREA), Autoroutes du Sud de la France (ASF), Société des Autoroutes Estérel, Côte d'Azur, Provence, Alpes (ESCOTA), Société des Autoroutes du Nord et de l'Est de la France (SANEF), Société des Autoroutes Paris-Normandie (SAPN), Société des Autoroutes Paris-Rhin-Rhône (SAPRR), and Société du Tunnel Routier sous le Mont-Blanc (STMB). These concessionaires, listed in Table 8.1, manage the Autoroute System for the Directorate of Routes within a contiguous geographic area.[17] Table 8.2 shows some of the principal routes being managed by the concessionaires, including kilometerage, average daily traffic (ADT), and average daily truck traffic (ADTT).[29]

The mixed-economy concessionaires are owned by public (51%) and private (49%) interests. Public interests include Departments, Regions, and the Communities. Recently, discussions surfaced pertaining to the consolidation of some of the concessionaires; three of the smaller eight mixed-economy concessionaires (AREA, ESCOTA, SAPN) have been absorbed as subsidiaries of two of the larger concessionaires (ASF, SANEF) to improve managerial control and to minimize supposed diversion of toll road revenues for non-Autoroute highway projects.

Compagnie Financière et Industrielle des Autoroutes (COFIROUTE) is the only remaining private concessionaire still operating in France. COFIROUTE is owned by two groups of contractors, those being SCAO (GTM, Fougerolle, and Colas) and SOCASO (SGE-SOGEA and EJL). Construction projects on the COFIROUTE system are not let for competitive bidding, but are distributed between the contractors that own COFIROUTE. Thus, because segments of the Autoroute are not awarded to the concessionaires competitively, Autoroute construction costs on segments managed by COFIROUTE are indirectly established and/or negotiated by the

Directorate of Routes (through the budgeting process) and the contractor that owns COFIROUTE.

Each concessionaire has a thirty-five year agreement with the Directorate of Routes to manage various segments of the Autoroute system. The arrangement the concessionaires have with the Directorate of Routes mirrors the relationship an utility company in the United States has with the State. The Minister of Finance sets the amount that the concessionaires can collect in toll revenues. The Minister of Finance also sets the limits on expenditures for new construction and for maintenance, in consultation with the Minister of Public Works, Transportation & Tourism.

Competitive bidding is not utilized by the Directorate of Routes when it selects a mixed-economy or private concessionaire to manage a segment of their Autoroute network, although negotiations occasionally occur where there is a possibility for more than one concessionaire to be awarded a segment of Autoroute without compromising geographic network continuity.

There are some high speed facilities which are not administered by the concessionaires. Most Autoroutes in or near urban areas are non-toll facilities. Autoroutes paralleling high speed (non-toll) facilities in neighboring nations, which are now easily accessible due to the open borders between European Union nations, are not toll facilities. For example, the (non-toll) A-35 autoroute parallels the A-5 autobahn east of the Rhein River in Germany, and the (non-toll) A-23 & A-25 autoroutes parallel the A-16 autoroute in Belgium.

Bretagne, which remains the most independent spirited of the regions in France, is the only Region which does not have existing or proposed concessionaire operated toll facilities. The Directorate of Routes program to upgrade important National Routes into grade-separated, limited-access LACRA facilities has been very ambitious in Bretagne, with approximately 500 km currently in service.

Several of the concessions indicated that a guiding philosophy used to manage their systems is that, if their system is poorly managed, motorists will use alternate routes. This philosophy holds true, in that there are very few noticeable pavement distresses encountered on the Autoroutes. It should, however, be noted that there are seldom alternate high-speed Autoroute or LACRA facilities (posted at either 130 km/h or 110 km/h) available. Presently, the only alternate routes often available are National or Departmental Routes which serve many villages and communities and which take twice as long, or longer, to travel.

8.1. Scetauroute

Scetauroute is the engineering organization jointly owned by the seven mixed-economy concessionaires. Scetauroute is a professional organization that provides engineering services, including preparing project development studies, as well as performing design work and contract administration duties. Scetauroute employees serve as resident engineers and project inspectors on the Autoroute projects, but they do not perform materials testing, which is performed by a

LRPC under contractual agreement with the concessionaire. Scetauroute also provides engineering services internationally.[30]

COFIROUTE, the privately owned concessionaire, is not an owner of Scetauroute and does not generally have any services provided by Scetauroute. COFIROUTE performs all of their design and other engineering services in-house or by contract, with the exception of materials testing which is performed by the appropriate LRPC.

8.2. Mission du Contrôle des Sociétiés Concessionaires (R/CA)

The Mission du Contrôle des Sociétiés Concessionaires d'Autoroute (R/CA) provides for oversight of the Autoroutes. The R/CA also sets criteria for new pavement construction for the Autoroutes. These criteria are generally safety related (sight distances, skid resistance). Other performance related criteria are also developed by the R/CA and included in the Scetauroute pavement design catalogue (discussions beginning on page 40 and 67 of this report). However, once projects are accepted, the concessionaires are solely responsible for setting the criteria for acceptable levels for the condition of pavements. This does not imply a lack of involvement by the R/CA; the R/CA has a stewardship relationship of the Autoroutes and works closely with the concessionaires in other activities.

For example, the R/CA works very closely with the eight concessionaires in the formulation of annual budgets for both construction and maintenance. The Secretary of Finance sets limits on both the amount that the concessionaires can collect, as well as the amount that can be used for financing new facilities and for funding maintenance. Because their system now generates revenue, this revenue is used both to pay off existing bonds as well as to finance new construction.

Table 8.1. Geographic Limits of the Concessionaires, 1993. [17, others]

Concessionaire	Regions of Operation	In-service km	Total km
ASF	Aquitane, Auvergne, Limousin, Languedoc-Roussillon, Midi-Pyrénées, Pays de la Loire, Poitou-Charentes, Provence-Alpes-Côte d'Azur, Rhône-Alpes	1 646	1 761
AREA	Rhône-Alpes	367	367
ESCOTA	Provence-Alpes-Côte d'Azur	418	418
COFIROUTE	Centre, Île-de-France, Pays de la Loire, Poitou-Charentes	735	794
SANEF	Alsace, Champagne-Ardenne, Île-de-France, Lorraine, Nord-Pas-de-Calais, Picardie	1 009	1 161
SAPN	Basse-Normandie, Haute-Normandie, Île-de-France	213	338
SAPRR	Bourgogne, Champagne-Ardenne, Franche-Compte, Île-de-France, Rhône-Alpes	1 331	1 530
STMB	Rhône-Alpes	105	105
	Bretagne	0	0

Figure 8.1. The majority of autoroutes in France are toll facilities. The cost for an automobile driver to travel the 229 km of the A-11 autoroute between Paris and Angers is F_r 105, or \$0.13/mile.

Table 8.2. Principal Routes of the French Concessionaires. [29]

Principal Routes & Cities		ADT (1992)	ADTT (1992)	Concessionaire	In-service km
A-1	Paris-Lille	48 778	12 545	SANEF	155
A-4	Paris-Metz-Strasbourg	16 989	3 035	SANEF	464
A-6	Paris-Beaune	32 804	6 188	SAPRR	260
A-7	Lyon-Orange	52 043	10 073	ASF	170
A-7	Orange-Aix	38 459	6 463	ASF	80
A-8	Aix-Menton	39 176	5 487	ESCOTA	205
A-9	Orange-Narbonne	38 270	7 908	ASF	192
A-10	Paris-Poitiers	28 774	5 144	COFIROUTE	285
A-10	Poitiers-Bordeaux	18 573	2 598	ASF	218
A-11	Paris-Le Mans	28 270	4 451	COFIROUTE	148
A-11	Le Mans-Anger	12 766	2 185	ASF	81
A-11	Anger-Nantes	13 671	1 933	COFIROUTE	65
A-13	Paris-Caen	28 313	3 938	SAPN	182
A-26	Calais-Reims	10 484	2 765	SANEF	262
A-31	Beaunne-Nancy	15 905	4 415	SAPRR	230
A-36	Beaune-Mulhouse	14 161	3 514	SAPRR	216
A-40	Macon-Chantillon	15 283	3 938	SAPRR	104
A-40	Chantillon-Le Fayet	15 115	3 210	STMB	104
A-41	Chambery-Bonneville	16 979	1 980	AREA	77
A-42	Lyon-Pont d'Ain	15 836	2 150	SAPRR	50
A-43	Lyon-Chamber	32 420	4 625	AREA	88
A-51	Aix-Sisteron	9 784	1 031	ESCOTA	100
A-52	Aix-Toulon	30 317	2 621	ESCOTA	74
A-61/A-62	Narbonne-Toulouse-Bordeaux	18 303	3 489	ASF	369
A-63	Hendaye-Dax	16 821	3 782	ASF	66
A-71	Orleans-Bourges	14 883	2 181	COFIROUTE	111
A-71	Bourges-Clermont	10 670	1 185	SAPRR	178
A-72	Clermont-St. Etienne	12 195	1 814	ASF	122
A-81	Le Mans-Rennes	16 538	2 878	COFIROUTE	93
Others					1 081
All Autoroutes					5 830

RESEAU AUTOROUTIER
ET LES SOCIETES D'AUTOROUTES
1993

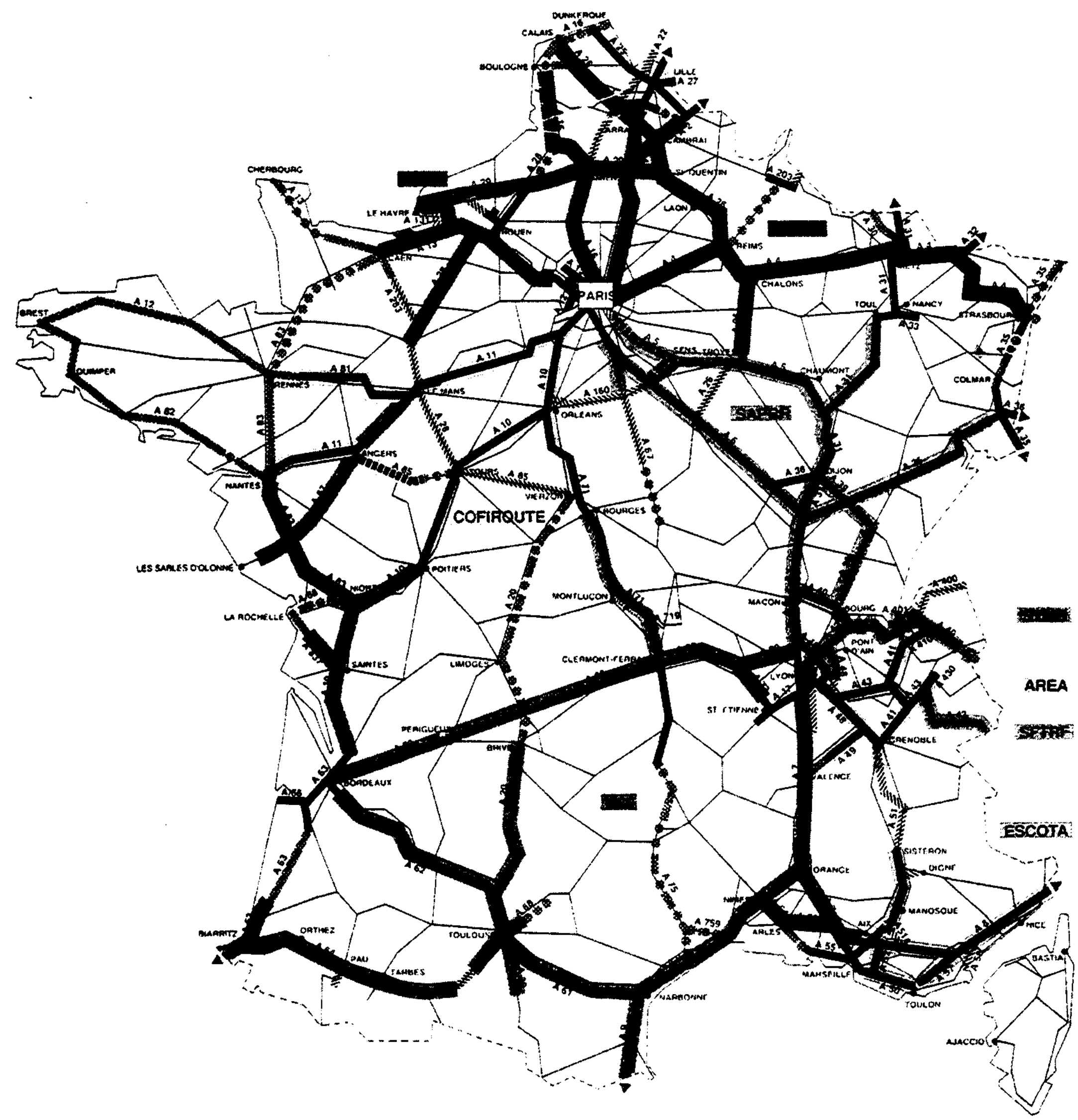

Figure 8.2. The Autoroute Network and the Concessionaires.
Source: Direction des Routes, France, 1993.

IX. Enterprises/Contractors

Approximately 80 percent of highway construction, rehabilitation, and heavy maintenance activities in France are performed by eight large, vertically integrated, enterprises/contractors. These firms perform all types of work, ranging from very small types of construction projects, such as sidewalk construction, to large highway projects, dams, tunnels, bridges, and shipping facilities. These enterprises/contractors have regional offices throughout parts or all of France as well as in other countries. Some of these enterprises are also subsidiaries of larger conglomerates, including banking, shipping, communications, and other interests which are sometimes partially owned by the national government. [3]

The four largest of these firms include COLAS/Sacer, Enterprise Jean Lefebvre (EJL), Screg Routes, and Cochery Bourdin Chaussé (CBC). Screg Routes is fully owned by the Bouygues Group, which also owns a large share of COLAS/Sacer. The remainder of the largest firms include Beugnet, Société Chimique de la Route (SCR), Gerland, and Viafrance. Table 9.1 lists the top firms which operate in France. Beugnet is the only firm of the top eight firms with direct roots as a family-owned company.

The remainder of the construction program involves smaller firms not affiliated with the larger enterprises. These smaller firms perform the majority of their work on smaller construction projects, such as intersection improvements, along Departmental and/or Communal Routes.

One reason contributing to the consolidation of the contracting sector appears to be because of the development of the Autoroute System and the manner in which this system was funded (bonds paid through toll collection). The design, construction, maintenance and management of short sections of Autoroutes was not conducive to revenue generation in the same manner that these activities could be accomplished with much longer sections. It was, and is, not uncommon to encounter 20 to 30 km long earthwork projects, and 30 to 50 km paving projects. This shift in emphasis from smaller, National or Departmental Route type projects from 1949 to 1970 to the longer Autoroute projects resulted in the incorporation and consolidation of smaller construction firms into the large enterprises. Contrasting this in the United States, many states have divided their projects into shorter sections, to maintain the full competitive participation of smaller firms in our highway programs.

Although it would appear that there is limited competition within France on highway projects, there is an aggressive and entrepreneurial spirit among the enterprises/contractors. There is also greater flexibility within their program allowing for the large enterprises to easily form partnerships or joint ventures. In addition, interestingly, some of the large enterprises do not prohibit their subsidiaries from bidding against each other on select projects.

Several of the large enterprises have become active in highway activities in other countries, including the United States. For example, COFIROUTE (the private Autoroute concession jointly owned by several of the large contracting firms) is a major partner that will participate in the design and construction of the 136 km California Mid-state Tollway from San Jose to Sacramento.[31, 32] COFIROUTE will operate this toll facility under a 35-year concession. COLAS/Sacer also operates in the United States. There is virtually no foreign contractor involvement in the Directorate of Routes program.

All of the large enterprises are very active in bituminous pavement construction and research. In addition, COLAS/Sacer, EJL, Screg Routes, Beugnet, and Viafrance all do some concrete pavement work through one or more of their respective subsidiaries.

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Table 9.1. Enterprises/Contractors Operating in France.

Enterprise/Contractor	Employees	Annual Contract Amount (Routes Only) Billion F, & Billion $	Pavement Activities	
			Flexible	Rigid
Beugnet	-	4.6 / 0.8 (1992)	X	X
Cochery Bourdin Chaussé (CBC)	-	-	X	
COLAS/Sacer	22 300	11.7 / 2.0 (1992)	X	X
Screg Routes	9 066	6.5 / 1.1 (1992)	X	X
Enterprise Jean Lefebvre (EJL)	16 459	-	X	X
Gerland	-	-	X	
Société Chimique de la Route (SCR)	-	-	X	
Viafrance	3 650	1.4 / 0.2 (1989)	X	X

X. Specifications

There are a multitude of standards or specifications pertaining to highways. These are produced by the Association Française de Normalization (AFNOR). These specifications are not bound but are sold individually at a cost of typically F_r 175 to 350 (or $30 to $60) each; the total cost of these 175 specifications is approximately F_r 40,000, or $7,000.[33] Contract documents reference but do not include applicable AFNOR specifications.

Directorate of Routes specifications are best described as method-based specifications. The use of end-result specifications (as used in the United States) is a seldomly used concept in France. End-result specifications are used on concessionaire-managed projects only when guarantees/warranties are utilized.

10.1 Normalization

Normalization (or harmonization) of standards and specifications is a frequent topic of conversation in Europe. Eighteen nations, which comprise the European Union (EU) and their European economic partners, are in the process of adopting existing standards or developing new standards for all items pertaining to trade. Existing standards will be adopted where practicable, e.g., International Organization for Standardization (ISO) standards for information systems, electronics, and other products. This effort is being undertaken under the auspices of the Comité Européen de Normalisation (CEN), or European Committee for Standardization.[34] Twelve nations currently comprise the EU (see Table 10.1). Three nations have voted to become full members, and three nations have economic ties in which many, but not all, of their specifications will conform with EU specifications. Several central european countries have also expressed interest in joining the EU. The twelve *current* EU nations will alone comprise an economic community of over 350 million people, similar to the combined population of the United States, Canada, and Mexico.

The French Directorate of Routes officials, with individuals representing contracting interests are formalizing other AFNOR specifications for consideration as CEN standards. The CEN standards will be made available in English, French, and German (the three official EU languages) as they are adopted.

For highways, the group responsible for developing standards is titled "CEN/TC 227, Road Materials". Within this technical committee, there are five working groups, one liaison working group, and several technical sub-groups as shown in Table 10.2.[34] Standards under development by CEN/TC 227 are in the process of being formally approved. Once formally approved and adopted, they will be made available from the CEN in Brussels. As can be imagined, this coordination of efforts receives attention on the European continent more so than does metrication in the United States. Finally, although the intent of normalization is to remove economic barriers, normalization continues to be controversial because it is feared by some that social and cultural values and institutions will be lost as Europe becomes one economic giant.

Table 10.1. European Union Nations.

Current EU Nations				Future EU Nations	Economic Trade Partners (CEN Participants)
Belgium	Denmark	*France*	Germany	Austria	Iceland
Great Britain	Greece	Ireland	Italy	Finland	Norway
Luxembourg	Netherlands	Portugal	Spain	Sweden	Switzerland

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Table 10.2. Working Groups for Standards Harmonization for Road Materials. [34]

Working Group	Description of Group
1	Bituminous mixtures
2	Surface dressing and slurry surfacing
3	Materials for concrete roads, including joint fillers and sealants
4	Hydraulic bound mixtures and unbound mixtures, including byproducts and waste materials
5	Surface Characteristics
L	Liaison

XI. Project Development

Project development and environmental studies for the Autoroutes are performed by the appropriate CETE offices and/or Scetauroute for concessionaire projects. Public hearings are conducted by the CETE. The procedure utilized for new Autoroute projects consists of five major phases: 1) public debate over the social and economic merit of a given project, 2) evaluation of alternative corridors, 3) solicitation of public sector input, 4) construction of the autoroute, and 5) post-construction studies for use on future autoroutes. [17]

Environmental features now required on all new Autoroute projects include closed drainage systems for rainwater detention and retention as well as for controlling accidental chemical spills. This feature alone cost F_r 19 million, or \$3.3 million on one 75 km project. [17] Traffic noise is also more of a concern in France (and in other countries in Europe) than it is in the United States. Noise walls, especially in urban areas, are also elaborate and designed to be aesthetically pleasing and/or artistically minded. Transparent plexiglas barriers are also commonly used across bridges for noise attenuation, resulting in uninterrupted noise barriers along mainline roadways, bridge approaches, and bridges. Other environmental features, such as restored or newly generated wildlife habitats and (overpass and underpass) crossings are common, even near urban areas. The cost of all environmental features on the Autoroute system during the past several years ranges from 3.4% to 8.9% of the total cost of the Autoroute. Table 11.1 shows the costs of environmental features as a percentage of all costs. [17]

A transportation mode now commonly included with new Autoroute facilities in the project development phase is the Train á Grande Vitesse (TGV), operated by Société de Chemin de Fer Nationale Française (SCNF), the nationally-owned train company. The TGV is a high-speed passenger train which travels on conventional tracks with improved geometrics at speeds of 250 km/h or more. Texas and Quebec are developing their high-speed passenger train systems using the TGV as the prototype. [31] In France, environmental studies are conducted for both the highway and railway, and sufficient right-of-way is acquired to adequately accommodate both facilities. Where the existence of the Autoroute has preceded a new TGV line, additional right-of-way is often acquired so that the operational characteristics of the Autoroute is not compromised. The TGV appears to be the mode of choice for many former Autoroute and continental airline users, and the Directorate of Routes indicated that decreases in Autoroute traffic in 1989 on the A-10 and A-11 of two percent were attributable to the TGV. [17a] In addition to the TGV cutting travel times in half versus driving, the TGV is less expensive than driving, considering fuel costs and Autoroute tolls.

Table 11.1. Economical Costs of Environmental Features. [17]

Route	Section	Length (km)	Average Cost Million F_r/km (Million \$/km)	Environmental Cost Million F_r/km (Million \$/km)	Environmental Cost Percentage of Total Cost
A-51	Manosque-Peyrius	30		1.4 (0.24)	4.3%
A-51	Peyrius-Sisteron	23	43 (7.5)	2.4 (0.42)	5.7%
A-54	Arles-Nimes	25	31 (5.4)	1.9 (0.33)	6.0%
A-26	Châlons-Troyes Nord *	75	24 (4.2)	1.7 (0.29)	7.0%
A-49	Voreppe-Bourg-de-Péage	62	32 (5.6)	1.5 (0.25)	8.9%

Figure 11.1. Inlet for typical closed drainage system encountered along newer autoroutes.

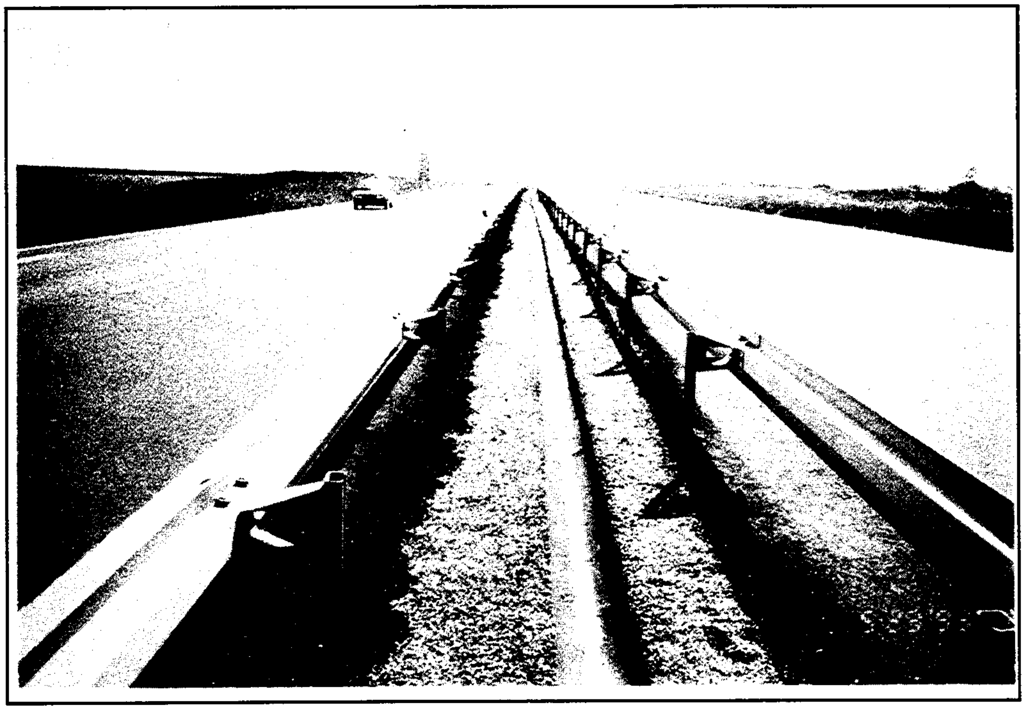

Figure 11.2. Median collector, tieing into closed drainage system.

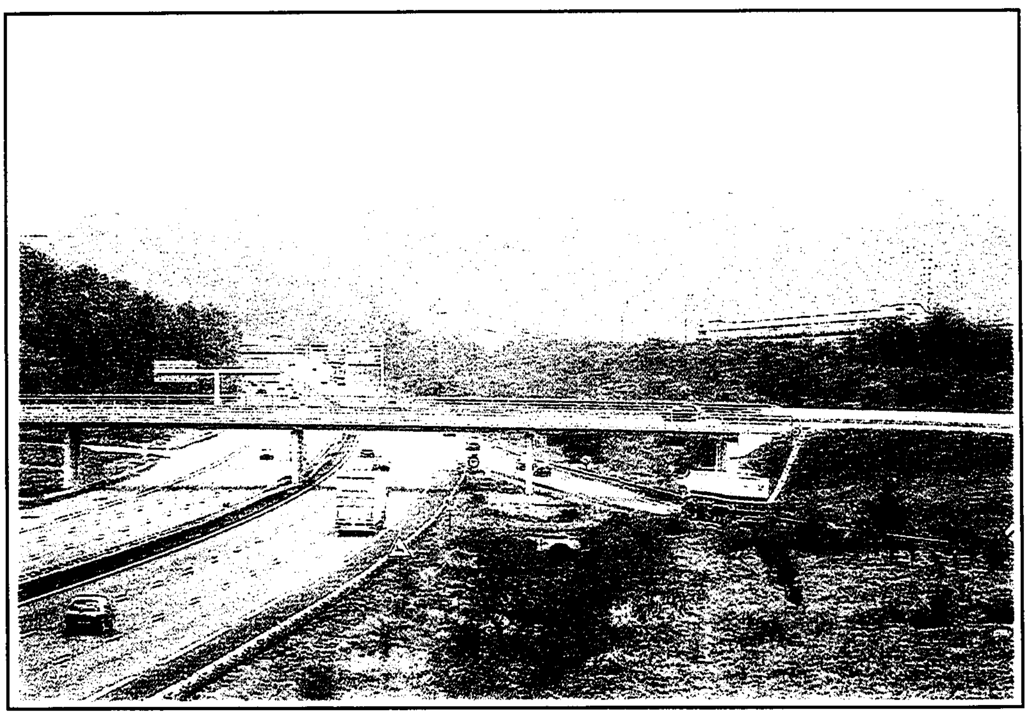

Figure 11.3. The TGV, parallelling the A-10/A-11 autoroute. [17a]

XII. Pavement Engineering

Pavement design, for Autoroutes, National Routes, and Departmental Routes, is accomplished using design catalogues.[35] Catalogues have been developed nationally which are used on non-toll Autoroutes, National Routes, Department Routes, and Communal Routes.[36, 37] In order to account for local conditions, catalogues have also been developed by at least two of the regional LRPC laboratories for use on non-toll projects. Finally, a catalogue has been developed by Scetauroute for use by the mixed-economy concessionaires for projects on the Autoroutes.[38, 39]

12.1 Pavement Types

There are a wide variety of pavement types which are and have been in use in France, including flexible, total-bituminous, semi-rigid, mixed-structure, inverse-structure, and portland cement concrete. The definitions of these pavement types, and their basic layer compositions as found in the Directorate of Routes and Scetauroute catalogue, are shown in Table 12.1.[35, 37, 39] Approximately 80 percent of the Autoroute System is comprised of flexible or semi-rigid pavements. The percentage of flexible or semi-rigid pavements is over 95% on National and Departmental Routes.

12.2 Pavement Type Selection

Pavement types are selected by the Directorate of Routes and the concessionaires based on a variety of factors, including initial costs, maintenance costs, materials availability, and local DDE or concessionaire preference. Economics appears to play the predominate role in the type of pavement selected, both from an initial cost viewpoint as well as overall life-cycle cost. Because of the current low prices of crude oil, virtually all pavements were being constructed with bituminous surfaces in 1993. On the Directorate of Routes projects, these pavements were predominately total-bituminous, semi-rigid, and mixed-structure. Some DDEs prefer to use only total-bituminous or mixed-structures; semi-rigid structures are more costly to maintain because of reflective cracking. The Scetauroute catalogue does not even include a semi-rigid pavement, and some concessionaires (e.g., ASF) no longer build mixed-structures because of their concern about reflective cracking.

Concrete pavements have, at this time, taken a back seat in the highway program in France. A research project (discussed on page 87 of this report) is reexamining five types of concrete pavement structures to assess the soundness of the design catalogues; slab thicknesses up to 420 mm (16.5 inches) are found in some catalogues.[39] Along another line, it was indicated that one LRPC was examining various applications of concrete pavements for use in urban areas. Concrete continues to be aggressively marketed in France as a material of choice in urban settings (in addition to and/or in combination with block paving and other labor intensive operations) because of its' pleasing appearance.[40, 41]

12.3 Pavement Design

Design catalogues are utilized in France to determine pavement layer thicknesses. The design catalogues are categorized by traffic and by platform support, as shown in Tables 12.2 and 12.3. For the Directorate of Routes projects (National and Department Routes and non-toll Autoroutes), there are 27 pavement types which have been approved for use since 1988. With each pavement type, up to four levels of traffic and up to three levels of platform support, resulting in up to twelve different designs for each of the 27 types of pavements. The pavement types include 20 bituminous surfaced and seven rigid surfaced pavements. Frost protection is also included in the catalogues, although most current designs for Autoroute and national Route projects are not driven by this feature. The French have historically used a significant amount of flexible surfaced pavements with a semi-rigid (cement, fly-ash, or slag stabilized) granular base material on their National Routes.

For the mixed-economy concessionaires, Autoroute pavement design is performed using design catalogues developed by Scetauroute. The Scetauroute catalogue for the Autoroutes includes 16 pavement types, and includes higher traffic and platform categories. Examples of this catalogue are shown in Figures 12.1 through 12.4. Note that the design catalogues show layer thicknesses in centimeters; contractual documents usually show layer thicknesses in meters.

Pavement designs as included in the catalogue assume that preventive maintenance will be accomplished throughout the duration of the life of the pavement structure. Thus, if it is stated that pavements are designed in France for periods of 30 to 40 years, it must also be stated that the wearing course of all of these pavements are anticipated to serve traffic for periods of approximately 8 to 9 years for both asphalt concrete pavements and portland cement concrete pavements before functional overlays are required, but that several structural overlays must also be accomplished in order to attain the 40 year life. [35, 39]

Traffic in the catalogue indicates the present total truck traffic exceeding 50 kN in the design lane. The Directorate of Routes and Scetauroute catalogues assume a constant growth factor of seven percent or four percent per year, respectively, throughout the design period. In addition, traffic data is handled according to the specification on traffic aggressiveness, shown in Table 12.4. An adjustment factor is included for growth factors which differ from four percent in the Scetauroute catalogue.

The legal single axle limit is (and will continue to be) 130 kN within France. Throughout the EU (i.e., when crossing national borders within the EU), the legal limits for loadings is as follows: 115 kN for single axles, 180 kN for tandem axles, 240 kN for tridem axles, and 400 kN total for 5 or 6 axle vehicles and 440 kN for container vehicles. [39] There is information in the Scetauroute catalogue, based on the allowable 130 kN single axle load, to convert the traffic categories to the 115 kN single axle loads as allowed in the EU. This conversion in the catalogue reveals that a 130 kN is approximately 1.6 times more aggressive to the pavement structure than a 115 kN single axle. The equivalency tables in the AASHTO Guide for Design of Pavement Structures [9, 42] roughly confirm this relationship for a single axle, and the same equivalency tables suggests that a 130 kN single axle causes approximately 4.5 times more damage to a pavement than a 80 kN (or 18 kip) single axle.

Although much has been made in several publications about allowable truck loadings in Europe being higher than in the United States, [1, 2, 4] indicating that European pavements can handle heavier loadings (and presumably implying that European pavements can handle higher total cumulative loadings), it should not be assumed that a majority of the truck traffic in the traffic stream approaches 130 kN or even 115 kN. A summary from a Scetauroute publication [43] is shown in Table 12.6, which when compared with the AASHTO equivalencies, reveals that the weighted load equivalency factor for the total truck stream for one segment of Autoroute is only approximately 1.7, which is not out of line with weighted load equivalencies encountered in the United States. Another document lists typical truck distributions (summarized in Table 12.7) encountered on highways in France. [44] Although these are only two examples, it illustrates that factors other than just maximum allowable loads need to be considered, for whatever purpose, when trying to formulate a comparison between truck loadings and impacts in Europe and in the United States.

A study was recently performed by Scetauroute addressing the overall aggressiveness of single, tandem and tridem axles on several segments of Autoroute pavements. A wide range of results were encountered on pavements managed by COFIROUTE, ASF, AREA, and SAPRR. [45]

The platform is the layer above the subgrade or embankment on which the pavement rests. Quite often, a thick layer of select material is placed above the subgrade or embankment to attain the mechanical properties required for the platform. [46, 47] For Autoroute projects, plate-load testing is performed during construction to evaluate the quality of the platform; since earthwork and paving projects are let separately, this information is used directly in the design of the new pavement. Often, however, earthwork activities are not complete when bid prices are accepted for paving projects. When the realized strength of the platform does not meet the expected strength used in the design of the pavement, supplemental agreements are executed under both the earthworks and paving contract to modify the pavement structure (and applicable unit prices) in conformance with the appropriate design catalogue.

When deviations in design catalogues are requested or suggested for National Routes (these variations are generally only one or two centimeters) in order to account for local conditions or proprietary materials, the design and analyses are usually performed by the LRPC. When pavement designs or analyses of Departmental Routes are performed, the Department reimburses the LRPC for their services.

Table 12.1. Pavement Type Description and Abbreviated Nomenclature.[35, 37, 39]

Pavement Type	Description	Directorate of Routes 1988 Catalogue	Scetauroute 1994 Catalogue
Flexible	Used on lower traffic routes, thin bituminous surfaces of 150 mm or less, total structure thickness ranging from 200 mm to 500 mm.	BB/GB/GRH	BB/GB/GRH BBTM+BBL/GB/GRH BBTM/EME/GRH
Total-bituminous	Surface bituminous, one or two underlying bituminous binder layer(s) totalling from 150 mm to 400 mm	BB/GB/GB	BB/GB/GB BBTM+BBL/GB/GB BBTM/EME/GB BBTM/EME
Semi-rigid	Surface bituminous, underlying one or two layer(s) treated or cement stabilized and 200 mm to 500 mm thick.	BB(+BBL)/GC/GC BB(+BBL)/GL/GL BB(+BBL)/GCV/GCV BB(+BBL)/GPz/GPz BB(+BBL)/GCV/CV BB(+BBL)/GC/SC BB(+BBL)/GL/SL BB/SL BB/SC	
Mixed-structure	Surface bituminous, bituminous binder ranging from 100 mm to 150 mm, subbase treated or cement stabilized ranging from 200 mm to 300 mm, bituminous structural layers exceed 33% of total structure.	BB(+BBL)/GB/GL BB(+BBL)/GB/GC BB(+BBL)/GB/GCV	BB/GB/GH BBTM+BBL/GB/GH
Inverse-structure	Surface bituminous, untreated granular base approximately 120 mm thick over a treated platform or hydraulically stabilized subbase.	BB/GB/SL BB/GB/SC BB/GB/GRH/GC BB/GB/GRH/SC BB/GB/GRH/SL	BB/GB/GRH/PF4 BBTM(+BBL)/GB/GRH/PF4 BBTM/EME/GRH/PF4
JPCP (undowelled)	Rigid concrete pavement, joint spacing 4.5 m to 5.0 m, over a lean concrete, a cement-treated granular layer, or a porous drainage layer. Includes compacted concrete pavements with a surface treatment.	BC/BM BC/GC ES/BCc/BCc BC/CD	BC/CD
JPCP (dowelled)	Same as JPCP, diameter of dowels ranging from 20 mm for 130 mm thick slabs to 45 mm for 500 mm thick slabs.	BCg/BB/MT BCg/BM (or GH, SH)	BCg/CD
CRCP	Continuously reinforced portland cement concrete pavement, reinforced with deformed reinforcing steel at 0.67 percent or with galvanized dimpled reinforcing strips from 0.34 percent to 0.40 percent.	BAC/BM (or GH, SH) BAC/BB/MT	BAC/BM BAC/BB

BB	Asphalt concrete	GH	Hydraulic bound aggregate	GRH	Untreated aggregate
BBL	Asphalt concrete binder	GC	Cement treated aggregate	BAC	Continuously reinforced concrete pavement
BBM	Thin asphalt concrete	GCV	Fly-ash treated aggregate	BC	Jointed concrete pavement
BBTM	Very-thin asphalt concrete	GL	Granulated slag treated aggregate	BCc	Compacted concrete pavement
BBUM	Ultra-thin asphalt concrete	GPz	Natural pozzolan treated aggregate	BCg	Dowelled concrete pavement
EME	High-modulus bituminous coated macadam	CV	Fly-ash/lime/gypsum treated aggregate	BM	Lean concrete
		SH	Hydraulic bound sand	CD	Drainage layer
ES	Surface treatment	SC	Sand cement	MT	Cement treated sand or lime stabilized
GB	Bituminous treated aggregate	SL	Granulated slag treated sand	PF4	Stabilized subbase > 200 MPa

Table 12.2. Design Catalogue Categories of Traffic.[35, 37, 39]

Category of Traffic (currently > 5 kN)		Directorate of Routes	Scetauroute
T_5		0-25	
T_4		25-50	
T_3		50-150	
T_2	T_2^-	150-300	150-200
	T_2^+		200-300
T_1	T_1^-	300-750	300-500
	T_1^+		500-750
T_0	T_0^-	750-2000	750-1200
	T_0^+		1200-2000
	T_x^- (a) T_x^+		2000-3000 3000-5000
	(a) T_{ex}		5000-8000

(a) Category added to 1994 Catalogue

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Table 12.3. Design Catalogue Subgrade/Platform Categories.[35, 37, 39]

Subgrade/Platform Category	MPa	Maximum allowable deflection (65 kn load) for acceptance during construction (95% of points tested)		Nominal Thicknesses, Other Descriptions
		Treated	Untreated	
PF_1	20 to 50			
PF_2	50 to 120	≤ 8 mm	≤ 15 mm	0.20 m to 0.80 m of select material
PF_3	120 to 200	≤ 5 mm	≤ 10 mm	0.35 m to 0.80 m of select material
PF_4 or P_{ex}	> 200	≤ 2 mm	≤ 6 mm	0.30 m to 0.55 m of select material

Table 12.4. Design Period & Traffic Aggressiveness used in Design Catalogue. [35]

Pavement Type	Traffic Aggressiveness, CA	Design Life
Flexible and Total-bituminous < 250 mm	0.8	15 years
Total-bituminous > 250 mm	1.0	15 years
Mixed-structures, Inverse-structures	0.8	20 years
Semi-rigid structures	1.3	20 years
Concrete pavements	1.3	25 years
Traffic T_{3+}, all pavement types	0.7	Based on pavement type
Traffic T_{3-}, all pavement types	0.6	Based on pavement type
Traffic T_4, all pavement types	0.5	Based on pavement type
Traffic T_5, all pavement types	0.4	Based on pavement type

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Table 12.5. Risk of Base Failure due to Fatigue. [35]

Pavement Base Type		T_0	T_1	T_2	T_3
GB	Bituminous Treated Base	2	5	12	25
GH	Cement Treated Base	2.5	5	7.5	12

Table 12.6. Axle Load Equivalencies, A-13, Flexible Pavement, 1981 to 1985.[90]

Class of Axle	Percent by Class of Axle	Load Aggressiveness (CA)	Weighted CA	80 kN Equivalency Factor	Weighted Equivalency Factor
50 to 70 kN	43.2	0.084	0.0363	0.7	0.30
70 to 90 kN	28.5	0.230	0.0656	1.4	0.40
90 to 110 kN	19.5	0.513	0.100	2.6	0.51
110 to 130 kN	6.7	1.000	0.0670	4.6	0.31
130 to 160 kN	1.8	2.295	0.0413	9.7	0.18
> 160 kN	0.3	4.563	0.0137	19.	0.058
	100.0		0.324		1.76

1992 Average Daily Truck Traffic on A-13 approximately 3938.

Table 12.7. Typical Axle Load Distributions in France.[90]

Class of Single Axle	Percent of all Axles	Class of Tandem Axle	Percent of all Axles
Under 13 kN	5.0	Under 81 kN	0.7
13 to 31 kN	19.3	81 to 108 kN	3.1
31 to 36 kN	1.3	108 to 134 kN	3.1
36 to 54 kN	2.4	134 to 152 kN	3.8
54 to 72 kN	14.8	152 to 161 kN	2.1
72 to 81 kN	2.8	161 to 170 kN	2.7
81 to 90 kN	2.0	170 to 179 kN	2.4
90 to 99 kN	2.4	179 to 188 kN	2.4
99 to 108 kN	2.5	188 to 197 kN	2.5
108 to 116 kN	2.5	197 to 206 kN	3.0
116 to 134 kN	2.7	206 to 224 kN	4.1
Over 134 kN	6.6	Over 224 kN	5.8
Total	64.3	Total	35.7

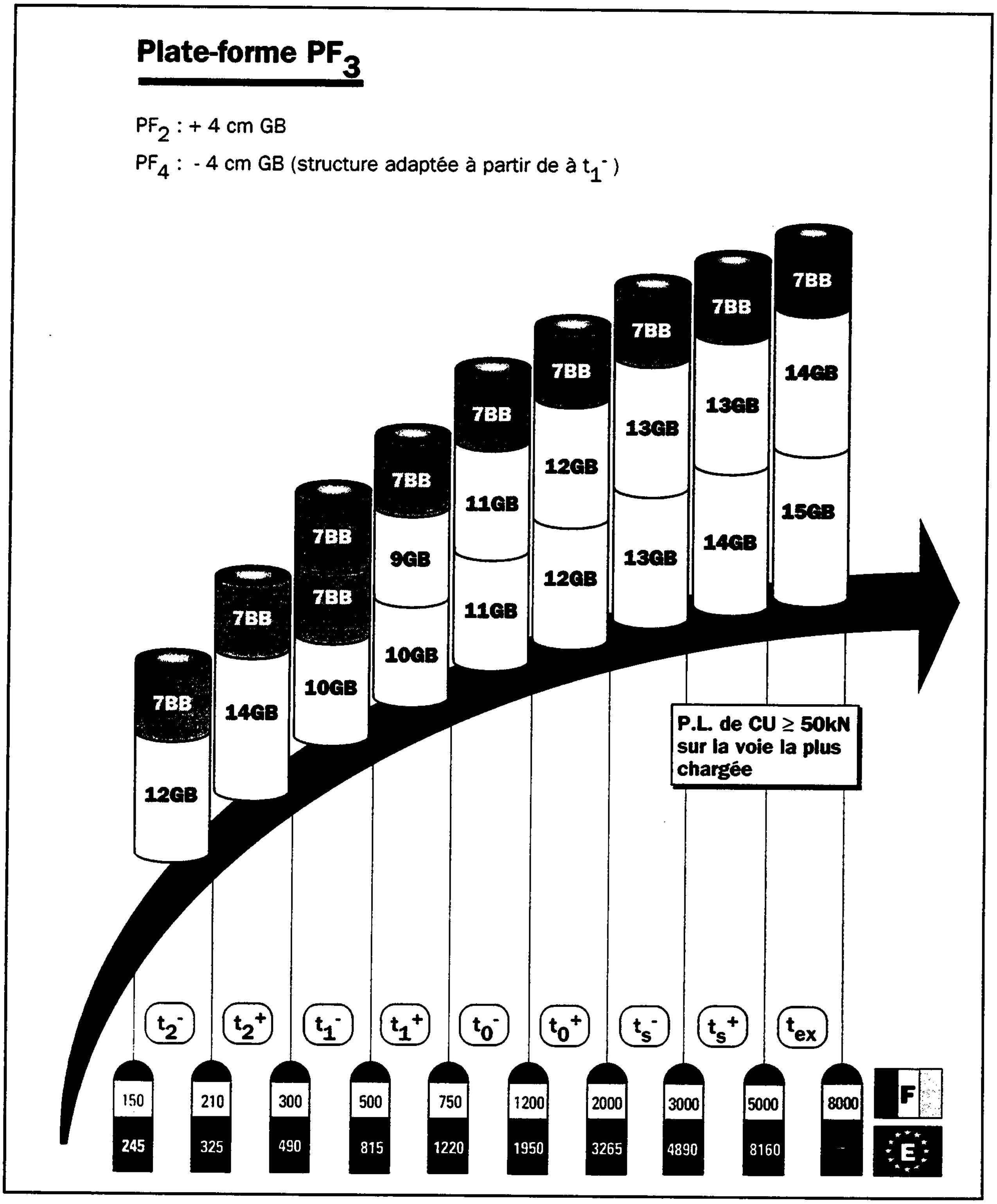

Figure 12.1. Example of a Design Catalogue for a Total-Bituminous Pavement.[39]

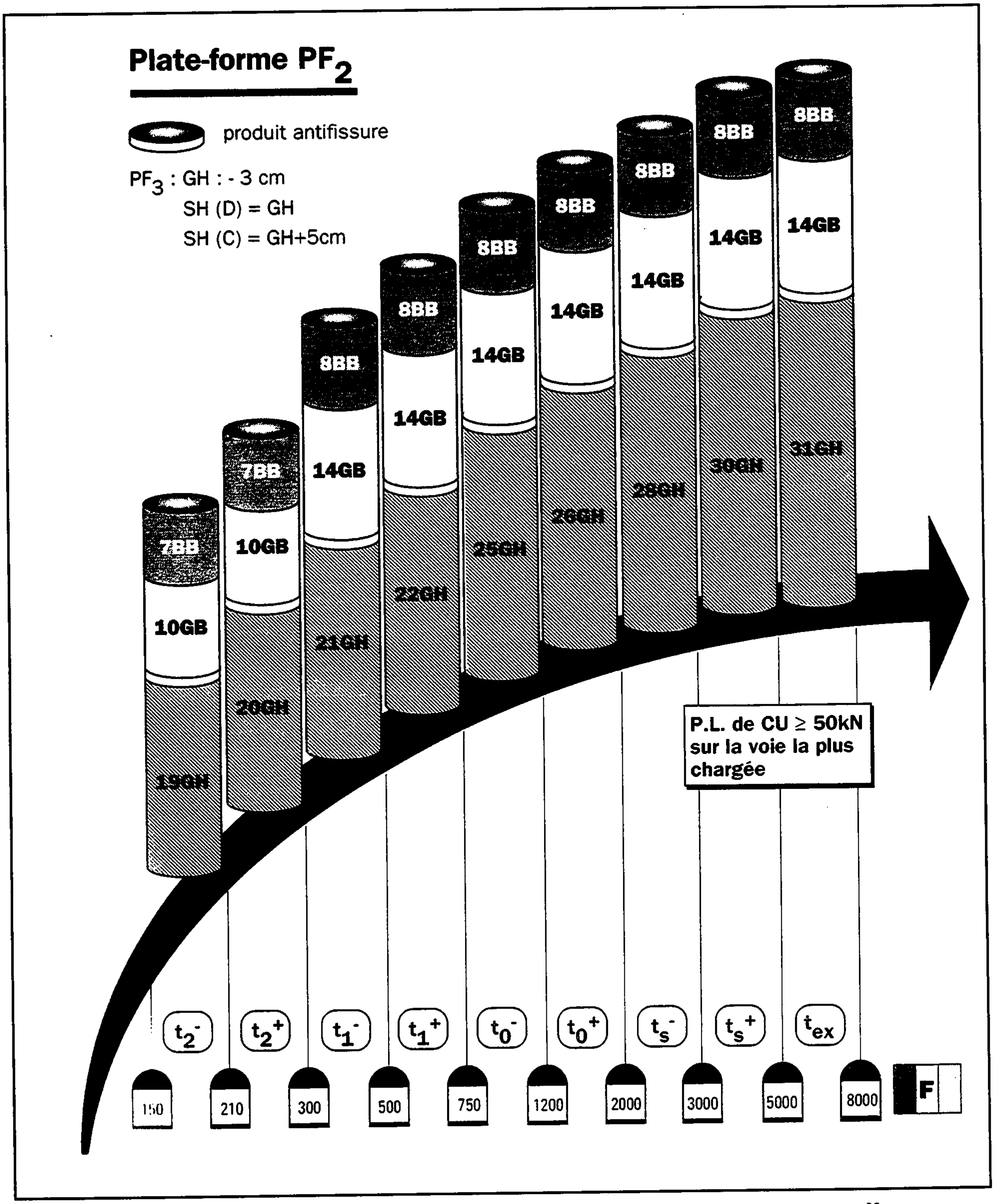

Figure 12.2. Example of a Design Catalogue for a Mixed-Structure Pavements.[39]

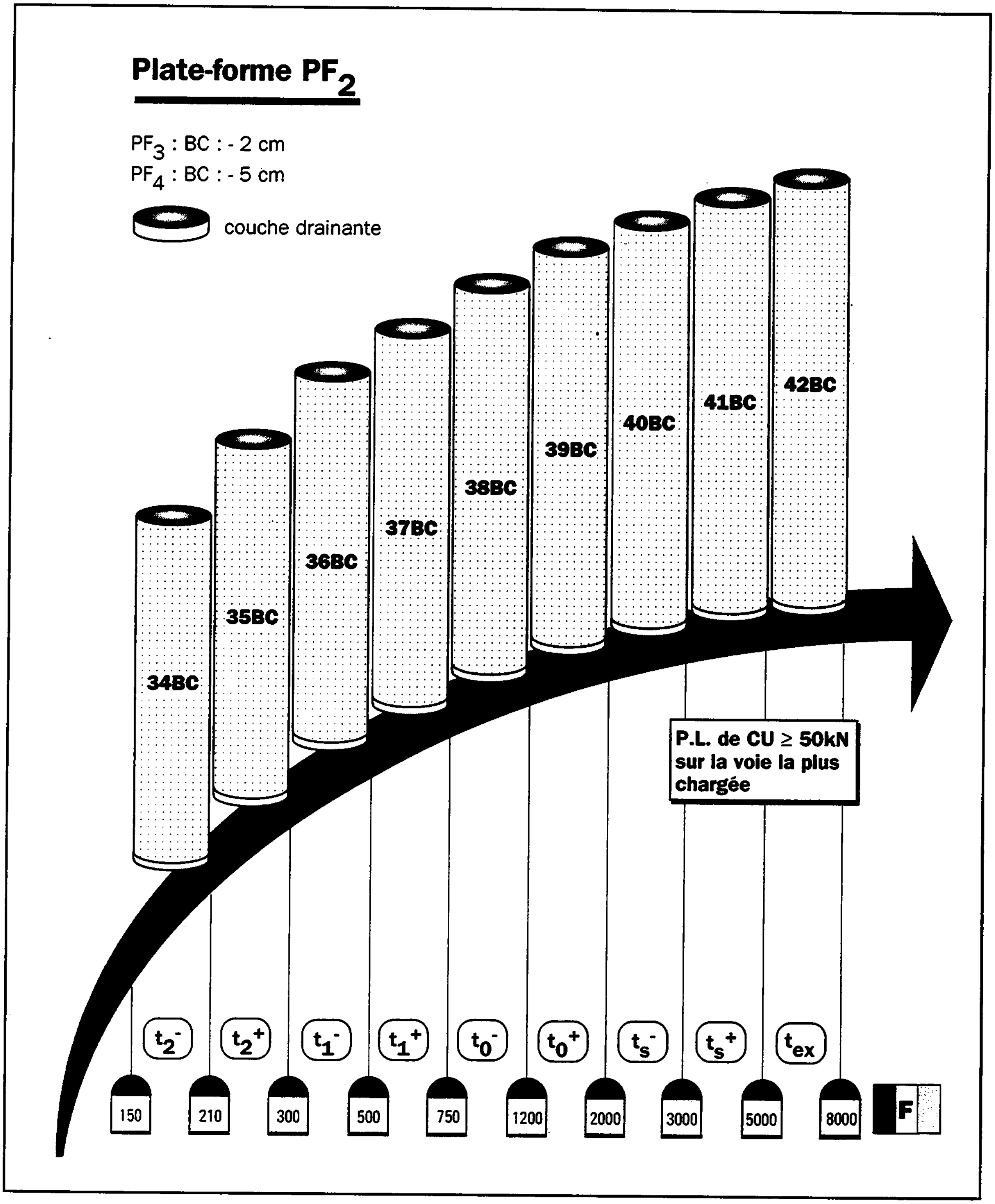

Figure 12.3. Example of a Design Catalogue for a Jointed Plain Concrete Pavement.[39]

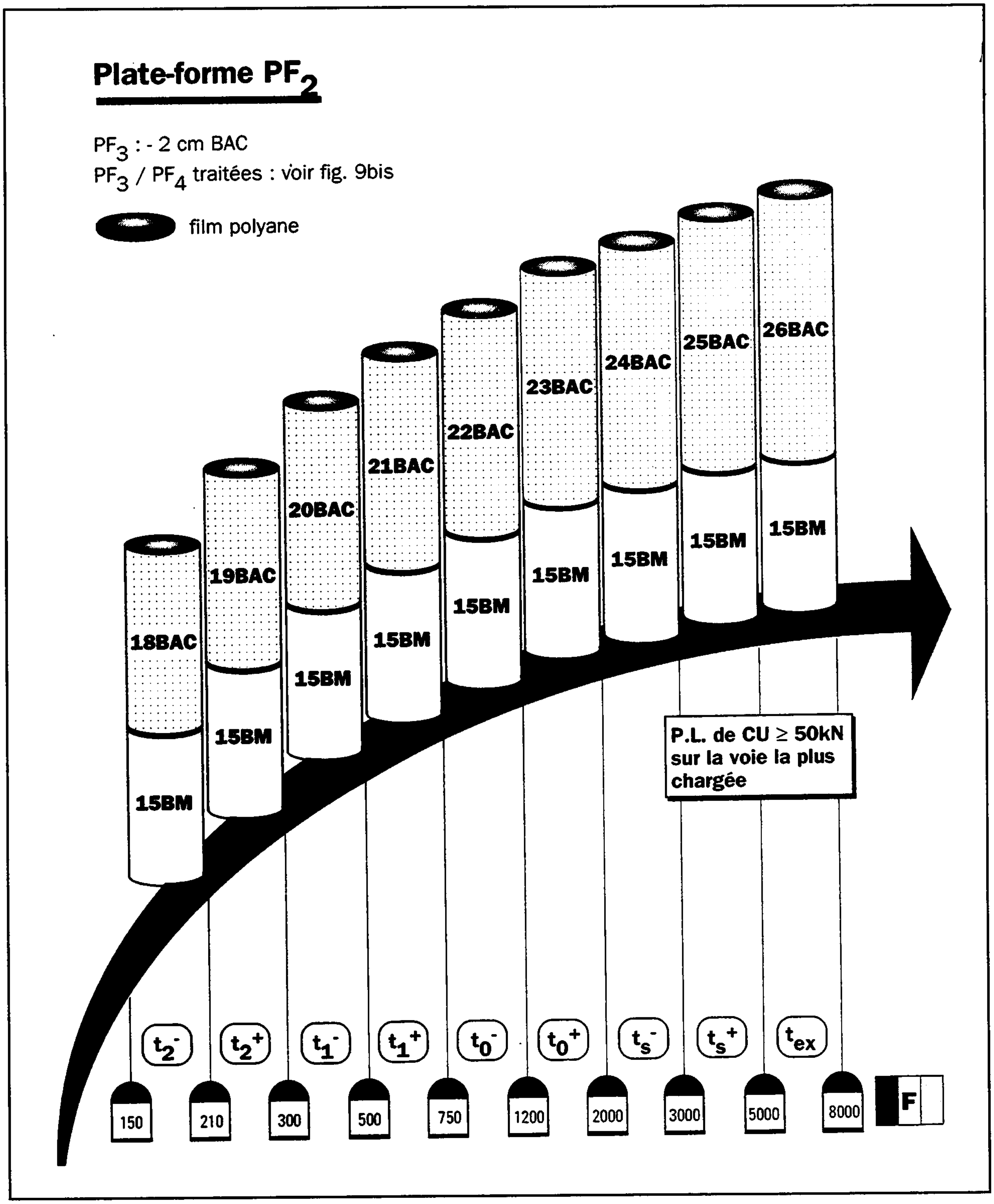

Figure 12.4. Example of a Design Catalogue for a Continuously-Reinforced Pavement. [39]

12.3 Development of Design Catalogues

The theoretical method for designing all pavement structures in France is based on Burmister's multi-layer semi-infinite model. It includes coefficients that take into account the pavement type, number of loads applied, risk of failure, and other factors. Rigid pavements are also designed using this model, and approximate correction factors have been built into the Burmister model to account for thermal gradients, interior loadings, and other factors. Theoretical allowable pavement responses (i.e., allowable stresses and allowable vertical and horizontal strains) have been established using standard material properties established using the Wöhler fatigue curve. Based on the anticipated loadings, pavements are designed so that the allowable responses are not exceeded. The same principles are used when an alternative design is submitted by an enterprise/contractor, except that the material property inputs used in the enterprise/contractor design is generally based on results from the accelerated bending fatigue test. In additional to the fatigue equations, an additional equation is used to verify that the vertical strain in bituminous layers does not exceed an established criteria so as to limit rutting potential. Table 12.8 includes some of the inputs used in the formulation of the design catalogues.

A SETRA/LCPC report in the final stages of development documents the fundamental assumptions used for developing pavement design catalogues in France; this work was also used in the development of the 1994 version of the Scetauroute catalogue.[35, 39] It is also envisioned that all seventeen LRPC regional laboratories will be developing design catalogues based on local conditions, materials, and experiences. The engineering principles behind the development of the Directorate of Routes catalogue(s) and the Scetauroute catalogue is the same. The design catalogues are based on elastic multi-layer theory for both flexible and rigid pavements. Differences in the catalogues are accounted by different assumptions (or transfer functions) used by the agencies developing the catalogues, which Scetauroute considers confidential.

An interesting observation pertaining to the comparison of the Directorate of Routes catalogue and the Scetauroute catalogue is that, in many cases, some (surface or underlying) layers are actually thinner in the Scetauroute catalogue (given the same category of subgrade support and traffic). One reason given for this is that Autoroute construction projects are controlled much more closely than are National Route or Departmental Route projects; there is less expected variability or risks associated with projects built by the concessionaires. Field visits of active projects confirmed that mixed-economy concessionaire projects were staffed and controlled to a degree similar to that found on Interstate projects in the United States. Departmental Route projects were virtually absent of any inspectors and quality control was performed by the contractor and with submission of certificates and test results.

Another reason for the differences in the design catalogues is that the Directorate of Routes catalogue assumes annual traffic volume increases of seven percent, whereas the Scetauroute catalogue assumes a four percent growth. Traffic data is obtained either from weigh-in-motion stations or, where available, from data collected at the Autoroute toll booths.

12.4. Bituminous Pavements

In addition to the many different types of pavement structures in use in France, there are a multitude of bituminous mixes which are used for new construction and for structural and functional overlays. Tables 12.8 through 12.11 illustrate some of the material and mechanical properties associated with these mixes. The trend in France is to use a relatively stiff high modulus asphalt layer with typically two to four centimeters of a polymer modified surface layer. Many engineers believe that this trend is perhaps resulting in the use of asphalt concrete structures in situations where rigid pavement structures were previously used.

Information was also obtained on the procedures used in France to develop and accept pavement mix designs. Test procedures and the sequence of testing varies depending on whether the material in consideration is being proposed for use as a surface or an underlying layer. The two main testing devices which are used are the Pavement Rutting Tester, which has been credited with reducing rutting in pavements, and the Gyratory Shear Compacting Press (PCG2), similar to our SHRP Gyratory Compactor. When developing a new mix design, the PCG2 is always utilized. In addition, satisfactory test results using the rut tester are required for all surface courses as well as for binder layers in pavement structures where a level of traffic of T_1 is anticipated. Unconfined compression testing and/or fatigue testing is also performed on all mixes intended for pavements with T_0 traffic levels.

One paper[48] presented at the annual Autoroute Seminar revealed the amount of rutting encountered on Autoroutes. In 1992, a survey of 4,960 km of toll Autoroutes (excluding the COFIROUTE system) revealed the following rutting levels in the outer lane:

77%		<	5 mm
17%	5	to	7 mm
4%	7	to	9 mm
2%	9	to	11 mm

Field observations confirmed that plastic rutting is a distress rarely encountered anywhere in France, particularly on the Autoroutes. One engineer instrumental in the development of the rut-tester and the PSG2 indicated that the cost of an expensive piece of testing equipment was well worth the investment when compared with the cost necessary to repair kilometers of a rutted or deformed asphalt pavement.

12.5. Alternative Pavement Designs

The Avis (Advisory) Techniques Committee, which is comprised of members representing the Directorate of Routes (SETRA, LCPC, LRPC), various contractors, and other industry representatives, performs tests and studies for suitability of use of proprietary materials, processes, and equipment. When this committee finds the use of such an item to be acceptable, its' use for five year periods is approved. There have been 64 Avis Techniques approved through January 1993. [49]

Material properties are documented by the Avis Committee and/or are obtained from testing property characteristics using either the bending fatigue test or sometimes the circular test track. When variances in the pavement design are requested, analyses are performed using an elastic multi-layer theory program titled Alize. The multi-layer elastic layer program is used to determine that the modified design does not result in excessive stresses and strains being induced on specific layers of the proposed pavement structure. If any of the criteria (as established in the Guide des Conception des Chaussées) are violated, the alternative design is denied.

When properly documented and supported, layer thicknesses are reduced (no more than 10 to 20 mm generally) on Directorate of Route or departmental projects. Layer thicknesses are, however, generally not reduced on Autoroute projects managed by the mixed-economy concessionaires.

The Bending Fatigue Testing Machine for Coated Materials is used at the LRPC in Anger to run all of the fatigue tests in France for project type uses. Contractors pay the LRPC to perform this testing when they wish to use a proprietary product which has not been approved by the Avis Technique Committee. A large slab of bituminous mix is compacted in the laboratory and cut into 48 specimens. To reduce (but not eliminate) data scatter, only 24 specimens are selectively chosen in order to run the fatigue test. Three initial levels of displacement are selected, and failure is defined when the initial force required to induce the displacement is halved. The strain-load application relationship is graphed, and the critical level of strain used in the design calculations is that needed to induce failure at one million applications.

The materials which have lent themselves foremost to reduced layer thicknesses in new construction and in structural overlays are the enrobés à module élevè (EME) or high-modulus bituminous coated materials and the bétons bitumineux à module élevè (BBME) or high-modulus asphaltic concrete materials. Table 12.10 shows some of the material properties associated with these type materials. High-modulus asphalt layers have been accepted by the Autoroutes, and are now included in their design catalogue. Table 12.8 shows the admissible stresses and strains allowed on specific pavement layers.

Table 12.8. Allowable Pavement Responses, Directorate of Routes.[35, 39]

Layer Type		Source	Modulus MPa	Allowable $\varepsilon_6 \times 10_{-6}$	Allowable σ_6 (MPa)
GC	Cement-treated aggregate	LCPC/SETRA	25 000		0.85
SC-2	Sand cement, class 2	LCPC/SETRA	17 200		0.75
GC-2 SC	Cement-treated aggregate Sand cement	Scetauroute			0.70
SL-2	Sand, slag-treated, class 2	LCPC/SETRA	12 500		0.65
GB-1	Bituminous-treated aggregate, class 1	LCPC/SETRA	7 000	70	
GB-3	Bituminous-treated aggregate, class 3	LCPC/SETRA	9 000	90	
GB	Bituminous-treated aggregate	Scetauroute	9 000	110	
EME-1	High-modulus bituminous coated macadam	LCPC/SETRA	14 000	100	
EME-2	High-modulus bituminous coated macadam	LCPC/SETRA	14 000	130	
EME	High-modulus bituminous coated macadam	Scetauroute	14 000	130	
BBSG	Asphalt concrete	LCPC/SETRA	5 400	100	
BBSG	Asphalt concrete	Scetauroute	6 000	120	
BC-2	Concrete, class 2	LCPC/SETRA	35 000		2.15
BC-5	Concrete, class 5	LCPC/SETRA	20 000		1.37

Table 12.9. Typical Gradations of Commonly used Asphalt Concrete Mixes.[50]

Thin and Ultra-thin asphalt concretes	BBTM 0/6 (a) (gap graded 2/4)	BBTM 0/10 (gap graded 2/6)	BBUM 0/6 (gap graded 2/4)	BBUM 0/10 (gap graded 2/6)
Aggregate ($\leq$ 5 mm)	70 to 80 %	65 to 75 %	75 to 80 %	75 to 85 %
Sand (80 μm to 5 mm)	20 to 30 %	25 to 35 %	20 to 25 %	15 to 25 %
Fines ($\leq$ 80 μm)	8 to 9.5 %	7 to 8.5 %	6 to 7 %	6 to 7 %
Asphalt Content	6.2 to 6.7 %	5.7 to 6.2 %	5.8 to 6.3 %	5.0 to 5.8 %
Polymers (when used)	0.2 %	0.2 %	0.2 %	0.2 %
Fibers (when used)	0.3 %	0.3 %	0.3 %	0.3 %

(a) designates gradation with maximum sized particles at 6 mm

Table 12.10. Typical Characteristics of Bituminous Layers.[35, 50]

Material		Typical Applications	Gradation	Average Thickness (mm)	Elastic modulus 15°C, 10 Hz
BBSG	Asphalt concrete		0/10 0/14	60 to 70 mm 70 to 90 mm	5400 Mpa
BBM	Thin asphalt concrete		0/10 0/14	35 to 50 mm	5400 MPa
BBC	Asphalt concrete chips		0/10 0/6	60 mm 30 mm	5000 MPa
BBTM	Very-thin asphalt concrete		0/10 0/14	20 to 25 mm	
EME I	High-modulus bituminous coated macadam	Subbase/base	0/10 0/14 0/20		14 000 MPa
EME II	High-modulus bituminous coated macadam	Subbase/base			14 000 MPa
BBME I	High-modulus asphalt concrete	Binder	0/10 0/14	50 to 70 mm 60 to 80 mm	9 000 MPa
BBME II	High-modulus asphalt concrete	Binder	0/10 0/14	50 to 70 mm 60 to 80 mm	12 000 MPa
BBME III	High-modulus asphalt concrete	Binder	0/10 0/14	50 to 70 mm 60 to 80 mm	12 000 MPa

* A 0/10 gradation is roughly defined as a material in which at least 90% passes the 80 μm sieve and 100 percent is retained on the 10 mm sieve.

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Table 12.11. Sensitivity of Modulus (MPa) of Bituminous Mix to Temperature.

Bituminous Mix Description		- 10°C	0°C	10°C	15°C	20°C	30°C	40°C
BBSG	Asphalt Concrete	14 800	12 000	7 200	5 400	3 600	1 300	1 000
EME	High Modulus Asphalt	30 000	24 000	17 000	14 000	11 000	6 000	3 000

Typical asphalt concrete modulus is 3 100 MPa at 20°C according to AASHTO.

XIII. Pavement Evaluation

Are pavements in France "better" or worse than ours? There are many measures (e.g., ride, lowest first cost, life-cycle cost, quality, road user satisfaction, etc.) which one would need to define before even trying to uniformly measure it. Although two pavements may be of similar condition, the performance history of each pavement would need to be known in order to assess how well, and under what type of environment and/or traffic a pavement has served the user. For these reasons, it is difficult to compare the condition of pavements in France to those of other European countries, let alone those within the United States.

Surface courses in France typically serve the user for approximately 7 to 11 years. Table 13.1 illustrates the performance life of semi-rigid and flexible pavements; it illustrates that the life expectancy of a surface course based on the time elapsed before an overlay (functional or structural) is needed is 9 years. The Directorate of Routes or the responsible Concessionaire established the criteria (cracking, rutting, skid, etc.) under which an overlay is required.

13.1 Pavement Management

Although pavement data has been collected for many years by the Directorate of Routes and by Scetauroute, sophisticated pavement management systems are only beginning to be used by the concessionaires. Only two of the systems, those developed by SAPRR and by COFIROUTE, were being effectively used in their management of their Autoroute network. COFIROUTE has also begun marketing their pavement management system.

Table 13.1. Percentage of Semi-Rigid Pavements Overlaid in France. [51]

Pavement Type	≤ 5 years	≤ 8 years	≤ 10 years	Mean Age
Pavement Strengthening/Maintenance Overlay				
Semi-rigid, constructed before 1975	45 %	81 %	90 %	5.25 years
Semi-rigid, constructed after 1975	14 %	36 %	-	9 years ±
Flexible pavement (BB/GB)	7 %	33 %	54 %	9.75 years
New Pavement				
Semi-rigid pavement (BB/GH/GH)	23 %	52 %	76 %	7.75 years
Mixed-structure (BB/GB/GH)	11 %	37 %	64 %	8.75 years
Flexible pavement (BB/GB/GRH)	17%	41 %	61 %	9 years
All pavement types listed herein	12 %	38 %	61 %	9 years

13.2. Autoroutes

The French Autoroute System (non-rigid pavements) is evaluated using the Système d'Inspection des Routes et autoroutes par Analyses Numériques et Optiques (SIRANO) equipment[52]. This high speed (70 km/h) equipment was developed by the MLPC and the LCPC in cooperation with concessionaires and other organizations. Data obtained by the SIRANO is stored in one common database by Scetauroute, the engineering association jointly owned by (and operating for) the seven mixed-economy concessionaires. This data is kept separate from information obtained from routes managed by COFIROUTE and the Directorate of Routes non-concessionaire Autoroutes and other National Routes. Although Scetauroute has control of all of the mixed-economy concessionaire data, they share this information very selectively. There is a concern that comparisons would be made between the condition of pavements managed by one concessionaire versus the condition of pavements managed by another concessionaire or versus the condition of pavements on non-toll Autoroutes.

Data collected by the SIRANO includes longitudinal profile (filtered wavebands on a 20 to 200 meter basis), texture (every 20 meters), surface deterioration (from continuous 35-mm film) via image processing on a scale of 1/200, and transverse profile (256 points) every 10 meters.

Each management firm has flexibility in developing operating modes for managing pavements. For example, each concessionaire selects both the criteria and the threshold values for deciding when heavy maintenance is required. These criteria include such items as skid, ride, rutting, and cracking. These same criteria (with different threshold values) are also used to develop guarantees, discussed later in this report. For example, SAPRR uses a threshold rutting level of 10 mm at one location or 8 mm average for scheduling heavy maintenance.

Although deflection testing has historically been used as one tool to determine the structural adequacy of a pavement, it is being used less often in France as a criteria for determining maintenance needs or for triggering guarantee clauses. A significant portion of the National Routes and Autoroutes are bituminous surfaced (but not flexible) pavements that are classified as total-bituminous, semi-rigid, mixed-structure, or inverse-structure. Consequently, there is negligible difference in the deflection using the French deflectograph (which measures vertical deformation under a truck axle of 130 kN moving at a constant speed of approximately 3.5 km/h) of good and fair performing pavements which are bituminous surfaced but are no longer truly flexible.

13.3. Image Qualite du Reseau National (IQRN)

Image Qualite du Reseau National (IQRN)[53] is an effort being undertaken by the Directorate of Routes to collect pavement condition data for roads on the National System. The first year of data was collected in 1992 for the entire National Routes and non-concessionaire Autoroutes. These routes represent an investment of over F_r 5.75 billion, or \$ 1 billion.

The two components of the IQRN are the structure or heritage rating (N_p), and the user or surface rating (N_s), both based on a scale of 20 to 0. The global rating (N_g) is simply the minimum of the heritage and user rating. One could infer that the structure rating is an engineer's indicator of the structural adequacy/capacity of the pavement; conversely, the surface rating is a quantifiable indicator of the user's perception of the adequacy of the pavement. Table 13.2 briefly describes the five classes.

A rating of 20 signifies that no work is required on that facility. Information is obtained (percentage of distress within each 200 m section of pavement) based on five types of distresses (deformation, transverse cracking, longitudinal and alligator cracking, polishing, bleeding, stripping, and repairs).

The objectives of the IQRN surveys are to obtain the zero point (as built data inventory and pavement condition), and to evaluate the effectiveness of the pavement program (specifically the effectiveness of maintenance) by priority (VRU, LACRA, GLAT, RL, RO) and/or political jurisdiction (region, department, etc.). Recall that maintenance funds for National Routes are allocated to the Departments based on a formula which is not legislatively mandated, and that considerable redistribution is routinely performed based on the observations of the Directorate of Routes. Consequently, some within the highway community believe that there is a danger that IQRN will eventually be used as the tool by which maintenance funds will be allocated to the DDE offices.

Table 13.2. Classification of IQRN Values. [53]

Class	Category	Description	IQRN
A	Excellent	No distresses	20
B	Good	Only localized distresses	19
C	Fair	Minor distresses throughout	16<N<19
D	Mediocre	Distress	13<N<16
E	Very Poor	Extensive distress	N<13

13.4. Routine Travel

Over 25,000 kilometers of various Autoroutes as well as National and Departmental Routes were driven in company with Directorate of Route representatives and independently during routine travel which provided an overall feel for the condition of the highway network. Generally, the opinion *of this highway user* is that the majority of their Autoroute pavements are in excellent condition; pavement distress is seldom (but not never) encountered. The National Routes ranged from very good to fair; Departmental Routes varied from very good to very poor. Quite often, the condition of a facility changed dramatically at departmental or communal borders.

Autoroutes on many of the concessionaire managed facilities were reviewed and typical types of distress encountered on their system were noted. Common distresses included reflective cracking (from the semi-rigid subbase through to the surface course) and isolated locations of ravelling; several segments of semi-rigid pavements were encountered where there was evidence of severe pumping. Segments of the concessionaire managed Autoroute system, approaching urban areas, were in a noticeably better condition than adjacent (non-toll) segments of Autoroutes. One of these non-toll facilities, A-6 south of Paris, appear to have been in service for quite some time and is scheduled for either reconstruction or major resurfacing in late 1994/early 1995.

The tolls on the Autoroutes are approximately F_r 0.60/km ($0.10/km or $0.15/mile) for passenger cars. It appears that this is one reason why a small percentage of the traffic continues to utilize the National and Departmental Routes parallel to the Autoroutes.

There appears to be very little truck traffic utilizing the Autoroutes on weekends. This is based on a limited number of observations. Weekday travel did show some higher truck traffic percentages, approximately fifteen percent on the A-11 autoroute.

13.5. SHRP and Long-Term Pavement Performance

The Long-Term Pavement Performance (LTPP) monitoring program in France includes approximately 20 test sections. [54] These include GPS-1, GPS-2, GPS-6A, and GPS-6B sections. Directorate of Routes officials indicated that because of Directorate of Routes efforts (under the direction of the LRPC de l'Ouest Parisien) to participate in the European Concrete Pavement Evaluation System (EuroCOPES) project being undertaken by the Permanent International Association of Road Congresses (PIARC), concrete pavements were not included under the LTPP program in France. Data for the French EuroCOPES sections are currently being evaluated under a FHWA administrated research contract. [55]

13.6. USAP Autoroute Seminar

The Union des Sociétés Française d'Autoroute à Péage (USAP) sponsored a seminar in Paris in November. The focus of this seminar was specifically on Autoroute pavements, and the seminar was broken down into several main themes pertaining to pavements, including loads, innovative techniques, noise and drainage, overlays and widening, and surface characteristics. [56]

Other topics discussed included the allowance and impact of higher axle loads (130 kN are allowed in France, 115 kN in the European Union, and approximately 90 kN in the United States). Higher total loads are also allowed in France (440 kN) than in other countries. The Autoroutes carry from 1,000 to 12,500 trucks per day, on average.

13.7 Pavement Technology Observatory

New technologies developed in the past twelve years as well as other standard practices in use in France were investigated over an eighteen month period by the Directorate of Routes. Topics were reviewed and monitored by a group of three or four engineers each representing the LRPC and CETE offices and the LCPC and the SETRA on the following topics: 1) porous asphalts, 2) very-thin and ultra-thin asphalt concretes, 3) reflective crack retardation and control, 4) surface treatments, 5) high modulus asphalt concretes and non-rutting asphalt concretes, 6) asphalt emulsions, 7) in-place recycling or reworking of asphalt concretes and/or cement-bound materials, and 8) concrete pavement maintenance. Information on the performance of these techniques, evaluations, prices, and recommended uses was discussed. A bound report which discusses each of these techniques was found to be an excellent source of information. [50]

Figure 13.1. The A-10 autoroute southeast of Paris, typical of autoroute pavements encountered throughout France.

Figure 13.2. The A-4 autoroute, east of Metz.

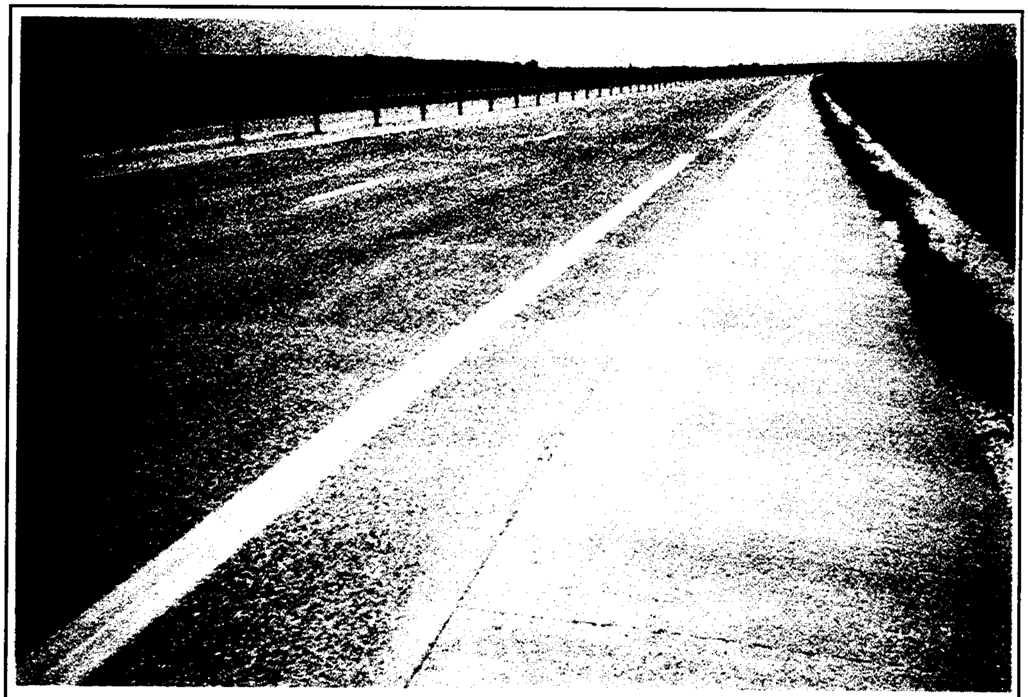

Figure 13.3. CRCP (with an exposed aggregate surface), A-71.

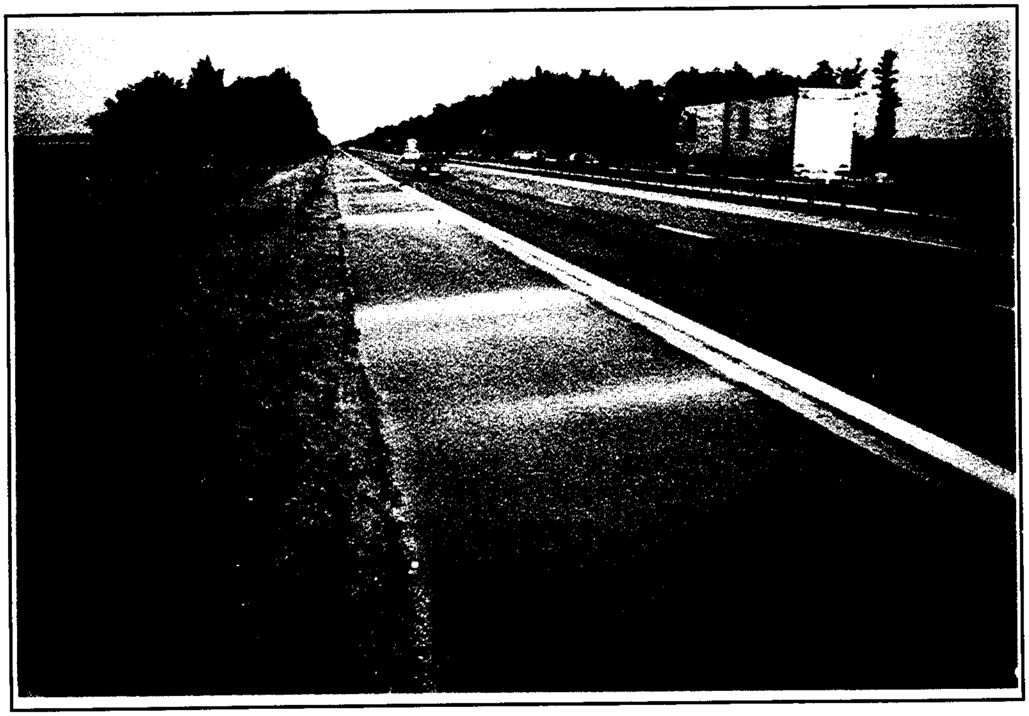

Figure 13.4. The A-31 autoroute south of Dijon. The base of this semi-rigid pavement has begun to pump through the transverse cracks in the asphalt surfaced pavement.

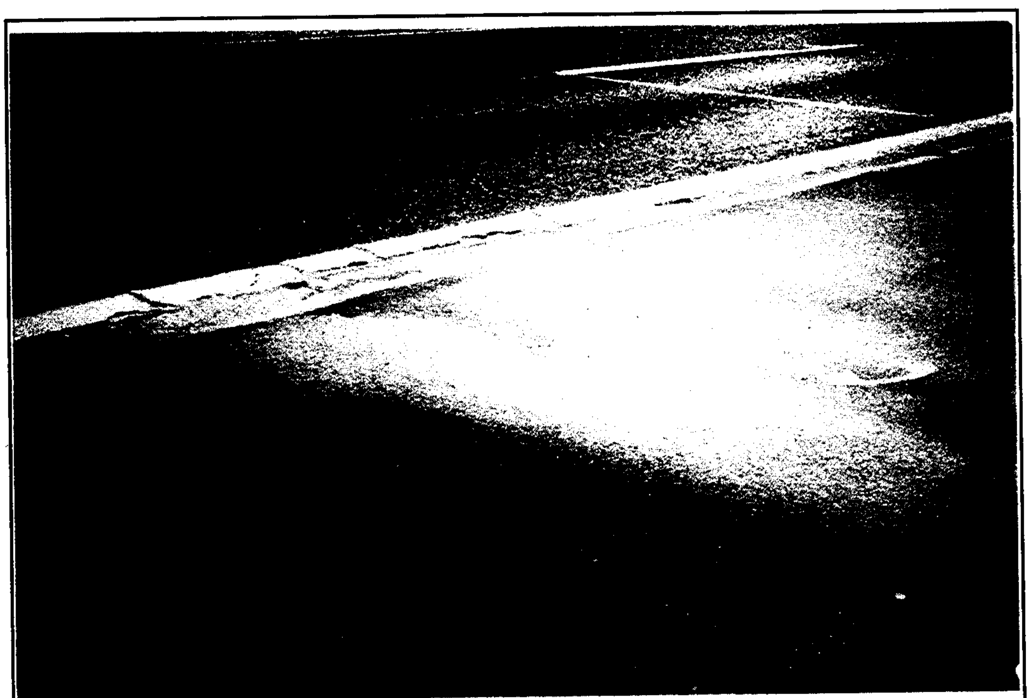

Figure 13.5. Fines pumped from the base, deposited on the shoulder.

Figure 13.6. RN-76, typical of national routes in central France.

Figure 13.7. RN-20, a semi-rigid or mixed-structure pavement, near Orleans. Bituminous patch shows signs of deterioration.

Figure 13.8. RD-52, typical of departmental routes in central France.

Figure 13.9. A typical urban street in Nantes.

XIV. Contracts

There are, on average, approximately 40,000 contracts (which includes approximately 2,000 purchase orders under $50,000) executed each year by the Directorate of Routes. These total approximately F_r 12 billion, or $2 billion, excluding the Autoroutes managed by the concessionaires [3]. Thus, the average contract is only approximately $90,000.

Separate contracts are usually executed by the Directorate of Routes for purchasing materials (aggregate, bitumen, etc.), and those materials are then furnished to the enterprise/contractor building the highway project. Major projects, including most concessionaire projects, are also separated into earthwork, structures, and paving projects. There also are escalation clauses in contracts which are generally included in any contract expected to last a duration exceeding one year, which minimizes the risk associated with inflation of materials and labor costs.

There is a very close working relationship between the Owner and the Contracting agencies in France. This relationship allows for the government to utilize three main types of contracts which are listed in Table 14.1. Contracts managed by Scetauroute for the seven mixed-economy concessionaires are either simple or variant.

On National Route and Departmental Route projects, use of alternate/innovative designs is encouraged. National and Departmental Route projects bid packages often require price submittal for one or sometimes even two additional "equivalent" alternate designs. These alternates could include a total-bituminous pavement, a semi-rigid pavement, and a mixed-structure pavement. Because of concerns about reflective cracking, as well as the lower cost of bituminous materials, many DDE and concessionaire staff now favor mixed-structures or total-bituminous structures over semi-rigid structures. Bid packages are not developed with alternate designs of asphalt versus concrete; the government does not allow the bid process to determine whether a pavement is asphalt or concrete. Life cycle cost analyses are generally performed by the Directorate of Routes or the concessionaire before projects are advertised for bid to provide adequate information in the decision of what type of pavement to build.

Table 14.1. Types of Contracts.

Type of Contract	Percent of Contracts
Simple (low bidder, no variances allowed)	65% to 75%
Variant (alternate designs allowed)	15% to 25%
Concurrent (open ended, no specifications)	0% to 5%

14.1. Contractor Section Criteria

Contracts are awarded in France on a variety of criteria which includes cost, quality control, pre-qualification (includes fiscal information, inspector certification, equipment certification, etc.) and other intangibles.

Although cost is not used exclusively to select contractors to perform work, it appears to be general practice to award a project to the low bidder when the cost differential between the low and second low bidder is more than five percent, assuming that the certifications and the quality control plan is satisfactory. This was especially true in 1993 because of the stagnant and/or recessionary state of the economy. Costs are not negotiated.

The contractor is responsible for submitting a quality control plan for the project in which a submittal is being proposed. If marginally acceptable, the Directorate of Routes does have the flexibility, informally, to advise or to make suggestions for improvements prior to awarding a project. There were no recollections by Directorate of Routes personnel of unacceptable quality control plans submitted by the experienced staffs of the eight large enterprises/contractors.

Time is considered an intangible and is a factor in determining prospective contractors, all else being equal. Incentive and disincentive clauses are not utilized.

Claims are virtually non-existent in France. Differences appear to be worked out without litigious intervention. In addition, although not policy, one is left with an underlying impression that the submittal of a claim could have a negative effect on the consideration of future bid proposals.

14.2. Warranties

Standard warranties on State and concessionaire contracts are generally only one year; it was indicated that this type of warranty is only used in cases of gross negligence.

Extended warranties are not permitted on State projects, but for the mixed-economy concessionaire managed projects on the Autoroutes, extended warranty periods are generally three or five years, and when they are used, they only apply to the surface layer.

Criteria for determining the acceptability of a road paving product over the life of a guarantee usually include skid, ride, rutting, and cracking. For example, SAPRR uses a rutting level of 6 mm minimum and 4 mm average for determining if the contractor is responsible for replacing the deficient material. Since the concessionaire and the contractor have financial interests in the acceptability of a guaranteed product, the concessionaires contract with the local LRPC to perform the appropriate testing services independent of the concessionaire and the contractor.

For a three or five year guarantee, the levels of responsibility for performing any repair or replacement work, should a pavement meet or exceed the threshold values specified in the agreement between the concessionaire and the contractor, is as shown in Table 14.2.

It is believed by some that the use of warranties on the surface layer of a pavement has an indirect positive impact on the quality of other aspects of the project.[57] For example, although underlying layers are constructed using method specifications and are not covered under the clause of the warranty, because distresses from underlying layers can manifest themselves in the surface layer, the contractor places more care in the construction of not only the surface layer, but also other layers as well.

On the other hand, there are some within the highway community who believe that the use of warranties for thin surface layers have marginal impact on quality and are not the driving force behind the quality of underlying layers (generally constructed using method specifications). On one project, a surface layer constructed with a warranty clause exceeded the allowable level of rutting; field testing indicated that the cause of rutting was clearly due to a rut-susceptible underlying layer (which was not covered under any warranty clause). In this example, the contractor not only shared the cost of replacing the (warrantied) surface layer, but was also willing to negotiate with the concessionaire to share the cost of removing and replacing the (non-warrantied) underlying layer as well. The end result was twofold; the pavement was repaired, and a good working relationship between the contractor and the concessionaire was maintained.

Guaranties on standard contracts are generally only 1 year. For the Autoroutes on the COFIROUTE system, COFIROUTE officials indicated that their warranty covered a four year period, which gave them essentially four years of zero cost maintenance. The cost of typical warranties was not available, although their engineers indicated that they pay a premium for this warranty.

14.3. Innovation

Avis (Advisory) Techniques is the title of the means by which the Directorate of Routes allow contractors to develop and implement the use of proprietary materials. This is often used in the effective implementation and use of polymer mixes for asphalt pavements. A panel lead by SETRA/LCPC and including representatives from other organizations, including competing contractors, is responsible for the review, and approval of use (for a period of five years, or more) on Directorate of Route projects.

Some of the techniques and/or products which are being or have been evaluated using this procedure include the following: porous asphalt pavements, very-thin and ultra-thin bituminous layers, reflection crack retardation/control, high modulus asphalts, and in-place recycling techniques.

One contractor (CBC) has developed a method to pre-crack cement-stabilized base courses and to inject bituminous sealant into the crack. Long-term crack development in semi-rigid pavements occurs at approximately 3 m spacings. A project previously constructed is currently being evaluated by the LRPC in St. Brieuc.

Another contractor (Beugnet) has developed a technique to rehabilitate low-volume flexible routes by blending cement with the existing pavement using a device called the ARC-700. This technique, which was used to upgrade many pavements under the coordinated pavement strengthening and overlay program, appears to be one which could be used to enhance low-volume county roads in need of base/subgrade enhancement. A project was apparently pursued several years ago to demonstrate this technique in Michigan, but the project was never constructed.

Other innovative features utilized in France include the use of continuously (galvinized-strip) reinforcing concrete pavements (CRCP-GS), which had been utilized on several autoroutes and is being promoted elsewhere for demonstration, and in the use of the Fressinet device to retrofit load transfer in existing concrete pavements.[50]

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Table 14.2. Concessionaire/Contractor Warranty Responsibility.

Length of Warranty Period	Mixed-Economy Concessionaire	Contractor
Three Year Warranty		
After the first year	0 %	100 %
1st to 2nd year	33 %	67 %
2nd to 3rd year	67 %	33 %
After the 3rd year	100 %	0 %
Five Year Warranty		
After the first year	0 %	100 %
1st to 2nd year	20 %	80 %
2nd to 3rd year	40 %	60 %
3rd to 4th year	60 %	40 %
4th to 5th year	80 %	20 %
After the 5th year	100 %	0 %

XV. Pavement Construction and Quality

On Autoroute projects, for example on the A-5 near Paris and the A-83 south of Nantes, the level of inspection appeared comparable to that found on typical Interstate type projects. A very well trained staff of inspectors closely monitored all facets of the operations underway. Asphalt paving projects routinely use electronic lasers over extended sections to control grades, even on lower base courses. It was also interesting to observe the role of the LRPC representatives in the on-site administration of the contract between the contractor and the concessionaire's engineering representative. Although the Directorate of Routes is not a party to the contract between the contractor and the concessionaire, LRPC representatives sometimes take very active measures to uphold the quality of the work being undertaken, demonstrating that the government (informally) exercises oversight in monitoring a concessionaire-financed construction project. Tables 15.1 and 15.2 show some of the criteria required on the Autoroutes by the R/CA for new construction.

A remarkable finding was the level of inspection encountered on Departmental Route projects. These type projects were monitored by the DDE to a much lesser degree than on the Autoroutes. On the Departmental Route 751 project visited, there was only one government engineer overseeing a multi-million dollar project. Materials project control was accomplished by the contractor.

Generally, local aggregates are used on highway construction projects. One exception mentioned where aggregates were transported from outside a local area was for aggregates used in surface courses. Higher quality aggregates are required in surface courses than in base or subbase layers, and because of a shortage of materials meeting the LA Abrasion and MDE requirements in the Paris metropolitan area, aggregates were being transported from western France to Paris.

15.1. Concrete Pavement Construction

There was no rigid pavement construction undertaken in France on the autoroutes in 1993, and little or none was foreseen for 1994. Concrete pavement construction in France was limited to rest-area paving, water retention/detention pond paving, and airfield pavements; concrete rehabilitation activities were limited to the Paris périférique, a controlled access Communal Route. Arrangements were therefore made for on-site visits of active rigid pavement construction projects in Germany, discussed later in this report.

Only three of eight concessionaires (SAPRR, Société des Autoroutes du Nord et de l'Est de la France (SANEF), and Compagnie Financière et Industrielle des Autoroutes (COFIROUTE)) manage a significant system of rigid pavements. Table 15.3 is an approximate breakdown of rigid pavements managed by the concessionaires.

Table 15.1. Selected Criteria for New Flexible Pavements on the Autoroute System.[39]

Criteria	Measurements	BB (surface)	BB (binder)	EME (binder)	EME (base)	EME (subbase)
Thickness	97.5 % ≥	d - 20 mm	d - 10 mm	d - 20 mm	d - 20 mm	d - 30 mm
Voids	95 % ≤	Duriez @ 18°C	Duriez @ 18°C	4 %	4 %	4 %
Ride, APL NBO (OC)	95 % ≥	6	7	6	5	-
Ride, APL NBO (OM)	95 % ≥	8	8	8	7	6
Ride, APL NBO (GO)	95 % ≥	9	9	9	9	9

Table 15.2. Selected Criteria for New Rigid Pavements on the Autoroute System.[39]

Criteria	Range	CRCP	JPCP (dowelled)
Thickness	97.5 % ≥	d - 10 mm	d - 20 mm
Strength, 7 days *	Minimum	2.5 MPa	
	Average	4.5 MPa	
Strength, 28 days **	Minimum	4.5 MPa	
	Average	5.5 MPa	
Ride, APL NBO (OC)	95 % ≥	7	
Ride, APL NBO (OM)	95 % ≥	8	
Ride, APL NBO (GO)	95 % ≥	9	

* 14 days for mixes with 80 kilograms/cubic meter of fly-ash
** 56 days for mixes with 80 kilograms/cubic meter of fly-ash

Table 15.3. Summary of Pavement Type by Concessionaire.[58]

Concessionaire	Network	Rigid	Pavement Type	
(a)	km	km	CRCP (b)	JPCP
COFIROUTE	734	125	X	
SANEF	1 017	125		X
SAPRR	1 363	700	X	X
Others	2 716	0		
Total	5 830	875		

(a) as of January 1, 1993
(b) reinforcing either deformed bar or galvanized strip

Figure 15.1. Fabric separator under concrete slab, A-6 rest area.

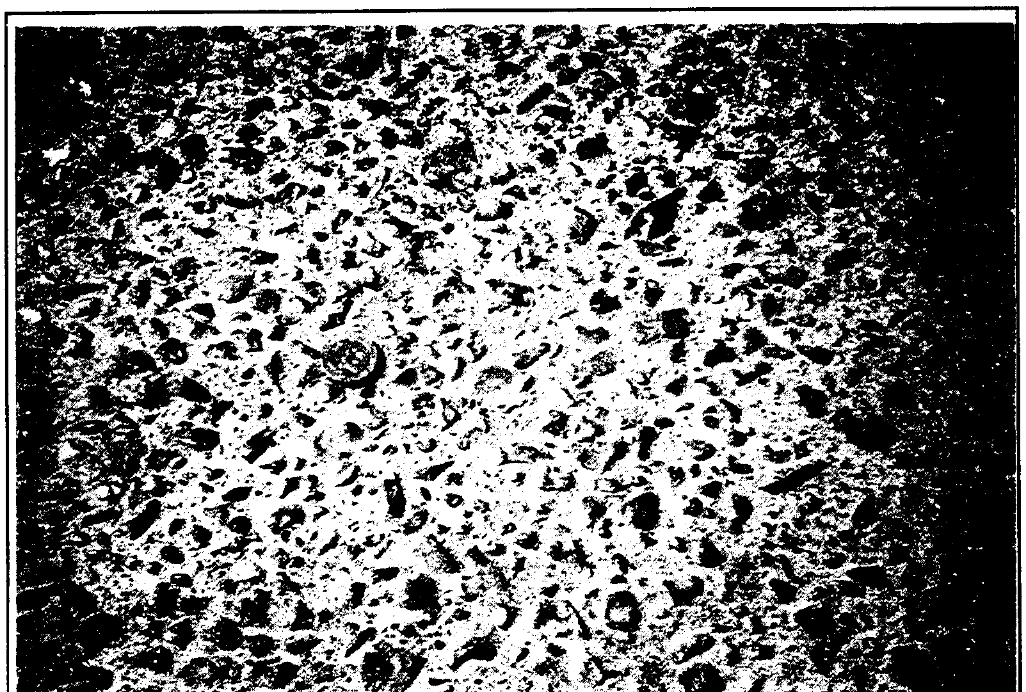

Figure 15.2. JPCP with an exposed aggregate finish, A-6 rest area.

XVI. Pavement Maintenance

France has always had a reputation for placing a high priority on preventive maintenance.

> In 1911, routes in France were considered to be the best in the world, and one reason for this was their commitment to maintenance. This commitment impressed Logan Waller Page, the third U.S. Highway Administrator, and with his encouragement, a two-year experimental maintenance project was undertaken to evaluate the French patrol approach to maintenance in the United States. This program was terminated when the United States entered World War I.[7]

There have, however, been periods during the history of France in which funds were not available for performing adequate maintenance; the period after World War II saw many routes fall into disarray.

As a result of the severe winter of 1962-1963, in which all National Routes were closed to traffic for an average of 30 days during the spring thaw, a systematic means of measuring pavement condition, using the moving deflectometer, was commenced in 1965. This effort, completed in 1967, concluded that 67% of the pavements on the National Route system were inadequate to handle current traffic, and that 33% were anticipated to fail rapidly. Consequently, the French began an aggressive resurfacing program entitled Coordinated Reinforcement in 1969, a program which continued through approximately 1990. Approximately 1,000 km per year were resurfaced. Because the type of pavements in-service, at that time, were predominantly flexible (versus semi-rigid), deflection testing was used to evaluate the condition of their network.

The design catalogues for pavements developed by both the Directorate of Routes and by Scetauroute include scenarios for preventive maintenance. These scenarios were developed based on the observed performance of the various types of pavements over the past forty years. Although not every pavement is treated in the manner which is included in these scenarios, it does reveal the level of intervention required in order to utilize a pavement structure for forty or fifty years. Table 16.1 shows some of the strategies used on the Autoroutes.[39]

Maintenance on the National Routes is performed on an extensive percentage of routes each year. Assuming that roughly ten percent of the National Routes are multi-lane facilities, and that the average width of a lane is 3.5 meters, the 18,300,000 square meters of routes receiving a functional overlay represents roughly 5,200 lane-kilometers, which is one-sixth of the entire National Route network.

16.2. Maintenance Budgets

The maintenance funds for each DDE is allocated based on a formula that includes categories based on the type of route and on the accumulated square meters of pavement surface within each category. This number is usually adjusted to attempt to balance funding allocations for the 96 departments. Once the funds are allocated to the DDE, it is their responsibility to determine priorities and to select the maintenance projects to be undertaken within the limits of their budget; the CETE works with the DDE regarding the coordination of maintenance projects across department borders, specifically to assure continuity of the National Route system.

The Loire-Atlantique DDE is responsible for 420 km of National Routes (RN). This DDE also serves as the engineering office for the Department Loire Atlantique performing studies, analyses, and services for 4,400 km of Departmental Routes (RD) within the department. The maintenance budget for 1993 includes F_r 26 million and F_r 80 million (approximately \$5 million and \$14 million) respectively for the RN and RD network in the Loire-Atlantique.

16.3. Maintenance Catalogues

Maintenance catalogues are routinely used on National and Departmental Routes in France to determine the type of maintenance to be performed on a segment of highway. These catalogues are based on existing traffic as well as on the existing levels of distress. Figure 16.3 on page 77 illustrates one of the new catalogues developed by SETRA.

16.4. Maintenance Expert System

An expert system used in France for maintenance is titled Erasmus [60], which is currently in an advanced stage of development, is a tool which is utilized by maintenance engineers in DDE 44 to confirm and verify their engineering hypothesis about how to rehabilitate a truly flexible pavement.

The SETRA is currently developing a new module for Erasmus that will be capable of analyzing semi-rigid pavements (of which the French have many). Erasmus is sold to other Directorate of Routes offices, and to other entities inside and outside of France. The cost of Erasmus is approximately F_r 400,000 (or \$70,000), which partially explains why only approximately 20 of the 96 DDE offices have purchased this software.

Table 16.1. Typical Maintenance Strategies Used by the Concessionaires.[39]

Age	Bituminous GB/GB GB/GN	Semi-Rigid GB/GH	Continuously Reinforced Concrete Pavement		Jointed Plain Concrete Pavement	
			BBTM/BAC	BAC	BBTM/BC	BC
3	-	SF	-	-	-	-
5	-	-	J (25% BAU) J (25% TPC)	J (100% BAU) J (100% TPC)	J (25% JT) J (25% BAU) J (25% TPC)	J (100% JT) J (100% BAU) J (100% TPC)
9	40 to 80 mm BB		BBTM		BBTM	
17*	RS (60%) 40 to 80 mm BB (40%)		F + BBTM (right lane)	BBTM	F + BBTM (right lane)	BBTM
25	RS (40%) 40 to 80 mm BB (60%)		150 mm GB + BBTM (5%) BBTM (95%)		F + 150 mm GB + BBTM (60% in right lane)	
33	RS (60%) 40 to 80 mm BB (40%)		150 mm GB + BBTM (95%) BBTM (5%)		F + 150 mm GB + BBTM (40% in right lane)	
41	RS (40%) 40 to 80 mm BB (60%)		RS (40%) 40 to 80 mm BB (60%)		RS (40%) 40 to 80 mm BB (60%)	

Legend:

SF	Crack Sealing	GB/GB	Total-bituminous Pavement
J	Joint Sealing	GB/GN	Bituminous Pavement over Granular Base
F	Milling & removing	GB/GH	Semi-rigid Pavement
BB	Asphalt Concrete	BBTM/BAC	Very-thin AC over Continuously Reinforced Concrete
GB	Asphalt Concrete Binder	BAC	Continuously Reinforced Concrete
BBTM	Very-thin (20 to 25 mm) Asphalt Concrete	BBTM/DE	Very-thin AC over Jointed Concrete
RS	Very-thin asphalt concrete or Porous asphalt or In-place recycling	DE	Jointed Concrete Pavement
		JT	Transverse Joints
		BAU	Outside Lane/Shoulder Joint
		TPC	Inside lane/Shoulder Joint

Table 16.2. Funding Levels used in Developing the Annual National Route Maintenance Budget.

National Route Classification	Pavement Maintenance Desirable (F_r/m²/yr)	Pavement Maintenance Possible (F_r/m²/yr)	Routine Maintenance Desirable (F_r/km/yr)	Routine Maintenance Possible (F_r/km/yr)	Winter Maintenance 4 Zones (F_r 1 000/km/yr)
VRU	10.0	10.00	280 000	183 500	5.25, 7.90, 17.75, 26.25
LACRA	7.5	6.00	48 000	35 000	5.25, 7.90, 17.75, 26.25
GLAT	5.0	4.00	23 000	17 000	3.00, 4.50, 9.00, 15.00
RL	4.5	3.50	23 000	17 000	3.00, 4.50, 9.00, 15.00
RO	3.5	2.00	17 000	9 000	3.00, 4.50, 9.00, 15.00

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Table 16.3. Use of Bituminous Concrete in Maintenance on National Routes, 1990.[50]

Mix type		Thickness (mm)	Square meters	Cost Index (b)	Percentage of total
BBM	Thin asphalt concrete	40	5 650 000	1.00 (b)	30
BBTM	Very-thin asphalt concrete	20 to 30	3 500 000	0.60 to 0.70	20
BBUM	Ultra-thin asphalt concrete	15 to 20	1 000 000	0.40 to 0.45	5
ES	Surface treatment	10 to 15	4 500 000	0.30 to 0.40	25
ECF	Cold mix surface	10 to 15	170 000	0.80 to 0.95	1
BB	Asphalt concretes	50 to 80	3 480 000	1.40 to 1.65	19
Total			18 300 000		100

(b) Based on the cost of BBM

TABLEAU N°4 — **OBJECTIF SURFACE : PERFORMANCES COMPAREES DES DIFFERENTES TECHNIQUES**

													Techniques destinées à un apport structurel	
	CRITERES / TECHNIQUES		ENDUIT SUPERFICIEL (ES) (1)	ENDUIT EPAIS (EE)	ENROBE COULE A FROID (ECF)	BETON BITUMINEUX ULTRA MINCE (BBUM)	THERMO REGENERATION	SABLE ENROBE CLOUTE	BETON BITUMINEUX TRES MINCE (BBTM)	MICRO BB 0/6 CLOUTE	ENROBE DRAINANT (ED)	BETON BITUMINEUX EN COUCHE MINCE (BBM)	BETON BITUMINEUX 0/10 CLOUTE	BETON BITUMINEUX (BB)
		N°	1	2	3	4	5	6	7	8	9	10	11	12
CONDITIONS D'EMPLOI	Epaisseur en cm		1 à 1,5	1 à 1,5	1 à 1,5	1,5 à 2	0 à + 2 cm selon enlèvement et apport	≃2	2 à 3	3	4	4	5 à 7	5 à 8
	Classe de trafic		< TO	< 1000 PL /j/sens	< 1000 PL /j/sens	Toutes (2)	Toutes	≤ T2	Toutes (3)	Toutes	Toutes (3)	Toutes	Toutes	Toutes
CARACTERISTIQUES INTRINSEQUES	Coefficient d'équivalence mécanique en épaisseur		Sans objet	Sans objet	Sans objet	Sans objet	Selon enlèvement et apport (1)	1	1	1	0,6	1	1	1
	Niveau d'adhérence	initial	++	++										
		à 5 ans				non connu								
	Etanchéité		++	++		A obtenir à l'interface			A obtenir à l'interface		A obtenir à l'interface			
	Bruit de roulement										++			
ETAT DU SUPPORT	Adaptation à une surface hétérogène (7)											++	++	++
	Amélioration de l'uni													
	Aptitude au reprofilage transversal						++						++	++
	Comportement à la remontée des fissures de retrait (sur GH)										non connu au stade actuel			
Indice de coût au m² (9)			0,3/0,4	0,85/1	0,8/0,95	0,4/0,5	1,2/1,5	0,8/1	0,6/0,7	1/1,35	0,8/1	1	1,8/2,2 (7 cm)	1,4/1,65 (7 cm)
OBSERVATIONS SUR LES TECHNIQUES			Risque de désordres rapides dans le cas de réalisation défectueuse					(10)		(10)	(11)			

RENVOIS

(1) Se reporter aux fiches techniques.

(2) Technique sur laquelle on possède peu de recul.

(3) De préférence à liant modifié pour les trafics ≥ TO.

(4) Selon la formule de l'enrobé d'apport.

(5) Avantage en adhérence à vitesse élevée.

(6) Selon importance du trafic et nature du support.

(7) Présence des réparations localisées, ressuages, etc...

(8) Selon que l'on réalise ou pas une 1ère couche en reprofilage d'ornière.

(9) Rapport du coût au m² de la technique choisie sur le coût au m² de la technique n° 10, ces techniques étant réalisées avec des constituants classiques.

(10) Techniques différentes à ne pas confondre. Se reporter aux fiches techniques.

(11) Technique présentant des particularités, à examiner en se reportant à la fiche technique.

Echelle des performances				
				++
mauvais	faible	moyen	bon	très bon

Cas des produits spéciaux d'entreprise : se reporter aux avis techniques (annexe N°2 de la notice d'utilisation)

Figure 16.1. Directorate of Routes Maintenance Catalogue.[59]

XVII. Other Issues

17.1. Crumb Rubber in Pavements

Beugnet is the only one of the eight multi-million dollar corporations (which perform approximately eighty percent of the highway work) in France that has experience in the use of rubber modified bituminous materials. All nine firms have extensive experience in the use of polymer modified bituminous materials. A field visit was conducted with a Beugnet and Directorate of Routes representative to discuss crumb rubber usage in France. Although no crumb rubber asphalt pavement work was underway, this visit afforded the opportunity to view the performance of asphalt pavements constructed with rubber obtained from used tires.

Beugnet has been using rubber modified mixes on their projects since approximately 1981. Stress-absorbing membranes and stress-absorbing membrane interlayers using crumb rubber were first used on various projects; approximately 3 million m² of these materials were used between 1982 and 1988.[61, 62]

Since 1982, Beugnet has developed a proprietary product line of paving materials, using their rubber-modified Flexochape® binder. Table 17.1 indicates the amounts placed on roads in France.

The Directorate of Routes realized a need for a durable porous surface material to address the following issues: hydroplaning, spray generated from truck traffic in rainy weather, and noise attenuation. This need was a major factor in the development of Drainochape®.

Drainochape® is a rubber modified bituminous material with approximately 20% voids, 6.3% binder, and aggregates minus 10 mm.

The first sections of Drainochape® placed on the A-1 autoroute (connecting Paris to Lille) in 1984 are still in service. This section of roadway carries 40,000 vehicles/day. Since 1992, a total of 2 million m², or approximately 320 lane-km, of Drainochape®, in thicknesses ranging from approximately 40 mm to 80 mm thick, has been used on the A-1. A review of several sections along this roadway in October, 1993 confirmed that all sections of this pavement were performing well and that little or no significant pavement deterioration had developed.

In 1990, Beugnet also performed in-place shoulder recycling of approximately 60,000 m² of Drainochape® on the A-1. This recycling was undertaken due to concerns that the shoulder was clogging and that the shoulder did not get the same cleaning effect from moving vehicles that the mainline receives. The French have not recycled (except for a very limited test section) any rubber modified mixes on mainline pavements.[63]

There was no documentation readily available from the Directorate of Routes which would support any difference in performance between rubber modified bituminous materials, polymer modified bituminous materials, and fiber modified bituminous materials.

There was little documentation readily available on the cost differential between polymer modified mixes and rubber modified mixes, which are used almost exclusively as surface course mixes. However, discussions with representatives from Beugnet indicated that crumb rubber modified mixes are somewhat more costly than the polymer modified mixes. A report prepared by the Directorate of Routes indicated that crumb rubber modified mixes were currently being used less and less (when compared with pure bitumens or polymer modified bitumens) in France.[64]

Costs of modified bituminous mixes appear to be approximately 15% higher than costs for pure bituminous mixes. One report suggested that drainable (modified) bituminous surface material cost approximately F_r 375 (or $65) per metric ton. Another report indicated that the average in-place cost of permeable (pure and modified) bituminous materials ranged from approximately F_r 20 to F_r 60 (or $3.50 to $10.50) per square meter for a 25 mm to 40 mm thick pavement.[50]

Directorate of Road officials believe that the use of waste products (i.e., used rubber tires) may become an issue in France in the forthcoming years. A cooperative agreement executed the fall of 1993 between the Federal Highway Administration and the Directorate of Routes cites their interest in two specific areas, one of which is our experiences with waste materials in asphalt pavements. In this regard, the Directorate of Routes sponsored a national symposium in 1994 to specifically discuss this topic.

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Table 17.1. Use of Rubber Modified Products by Beugnet.

	m²	through
Drainochape®	4 000 000	1992
Microchape®	2 000 000	1988

XVIII. Test Equipment

Some of the different types of testing devices used to measure pavement materials or to measure the performance of in-service pavements are briefly discussed. Most of these MLPC devices were developed at the CECP as a result of research efforts by the LCPC and the LRPC facilities.

18.1. Micro-Deval Testing (MDE) Apparatus

This apparatus (Figure 18.1) evaluates the wear resistance characteristics of aggregates used in pavement structures. Abrasion is produced by placing a sample of aggregate material with small steel balls (shown in Figure 18.2) into a cylinder, and rotating the cylinder at 100 revolutions per minute; the test is usually performed with water. This test is used in addition to the Los Angeles abrasion test for assessing the quality of aggregates. [65] Several engineers indicated that they felt the micro-deval test results give a much more representative indication of how aggregates perform in moist environments. The Directorate of Routes has developed a catalogue for classifying aggregate materials based on levels of traffic and on the layer for which the aggregate will be used. Typical requirements for aggregates used in high traffic volume surface treatments and high traffic volume surface course asphalt concretes are, respectively, $\leq$ 15 and $\leq$ 20 percent for the LA Abrasion Test and $\leq$ 10 and $\leq$ 15 percent for the MDE. [66]

18.2. Video Grader - VDG 40

This apparatus, in development, determines particle size distribution of aggregates greater than 1 mm. This device is generally used by aggregate producers in a production line to quickly assess product homogeneity. [65] This is an example of a testing device developed by the LCPC for use by the private sector.

18.3. Methylene Blue Test

This device is used to characterize the activity of clay contaminants. The test consists of measuring the quantity of methylene blue needed to change the absorbance of a suspension of material passing the 80 μm sieve. [65]

18.4. Tensile Testing Machine for Hydraulic-Treated Granular Materials

This device tests the tensile properties of granular materials treated with cement or pozzolan materials; the specimen is prepared into an hour-glass shaped form. The machine automatically provides stress-strain relationships, and the pneumatic loading can be selected for each test. [65]

18.5. Pavement Rutting Tester

This device (Figures 18.3 and 18.4) was developed to evaluate the rutting resistance of bituminous bound aggregate materials. Rectangular specimens of bituminous materials are subjected to repeated passes of a wheel fitted with a tire, inducing permanent deformations. Loads (300,000 cycles at 60°C) are induced at the same location. Specimens are prepared in rectangular molds using the MLPC Plate Compactor. Bituminous engineers throughout France believe that this device, used in conjunction with the MLPC Gyratory Shear Compacting Press PCG2, has been instrumental in reducing plastic rutting in bituminous pavements.[67, 68] The State of Colorado conducted an experiment to evaluate this device with pavements of known field performance. It was concluded that, although this equipment was overly severe for the temperature and environmental conditions encountered in Colorado, mixes that passed this test did not rut in the field, and all sections that rutted in the field failed the French specifications.[69] This equipment was also successfully used on a demonstration project in Saudi Arabia to control rutting. The cost of this equipment is approximately $200,000.[70] Figure 18.1 is a photo of this device.

18.6. Bending Fatigue Testing Machine for Coated Materials

This device performs alternating bending fatigue tests on trapezoidal specimens of bituminous mixtures. The force that can be exerted on the specimen ranges from 10 N to approximately 500 kN; the displacement at the head of the specimen ranges up to 1 mm. The results, which are used in alternate pavement design applications, have been instrumental in allowing the use of proprietary bituminous mixtures on Directorate of Route projects.[65] The cost of this equipment is approximately $250,000.[70]

18.7. Dynaplate

This device is used to evaluate pavement subgrades for design purposes and for acceptance during Autoroute project construction. The Dynaplate is an impulse generator that applies a dynamic loading equivalent in intensity and duration to that caused by the passage of a 130 kN axle at 60 km/h, using a weight falling on an annular array of springs mounted on a plate applied against the soil. The ratio of the height of rebound of the weight to the height from which it was dropped is used to determine the modulus of the soil. The microprocessor-based measurement and analysis system records the fall and rebound heights, the modulus, and the distance travelled. These results are read out on the printer and stored for later processing. The whole system, which has a mass of 500 kg, is permanently installed on a pick-up truck (see Figure 18.5); the measuring rate is 25 points per hour at 3 impacts per point.[65]

18.8. APL Ride Device

The Longitudinal Profile Analyzer (APL) is a system for measurement of the longitudinal profile of pavements in service or under construction. It can be used to locate and quantify evenness defects, whether caused by degradation by traffic or occurring during the construction of the successive pavement courses. The system takes the form of one or two single-wheel trailers (Figure 18.6), operating in one or both wheel paths.

Vertical movements of the wheel result in angular travel of the beam, measured with respect to the horizontal arm of an inertial pendulum, independent of movements of the towing vehicle. This measurement is made by an angular displacement transducer associated with the pendulum; rolling surface undulations in a range of plus or minus 100 mm are recorded for wavelengths in ranges from 0.5 to 20 m to 1 to 50 m, depending on the speed of the vehicle. The device must be operated at a constant speed ranging from 15 km/h to 140 km/h. Acquisition and storage of the measurements is by a microcomputer; data may be analyzed by the procedure of the user's choosing (e.g., IRI, APL, etc.). APL NBO values are used for describing ride characteristics for three types of wavelengths: short (OC) at 0.7 m to 2.8 m, medium (OM) at 2.8 m to 11.2 m, and long (GO) at 11.2 m to 44.8 m. An APL device is also owned by the United States Air Force for their use in evaluating surface characteristics.

18.9. PCG2 Gyratory Shear Compactor

The Gyratory Shear Compactor (Figure 18.7) is the device used in France to optimize the compactibility of asphalt mix designs. It was developed in the 1960's from the Texas gyratory shear compactor. The use of this device, in conjunction with the rut tester to control rutting, allows for the optimization of contradictory properties (high coefficient of internal friction and low void ratio) by being able to predict the in-situ void content. [67]

The FHWA Office of Research & Development and the Colorado Department of Transportation have each purchased a Gyratory Shear Compacting Press (PCG2) for research and asphalt mix evaluation. These devices were built at the CECP and were screened and tested at the LRPC in Anger prior to shipment to the United States.

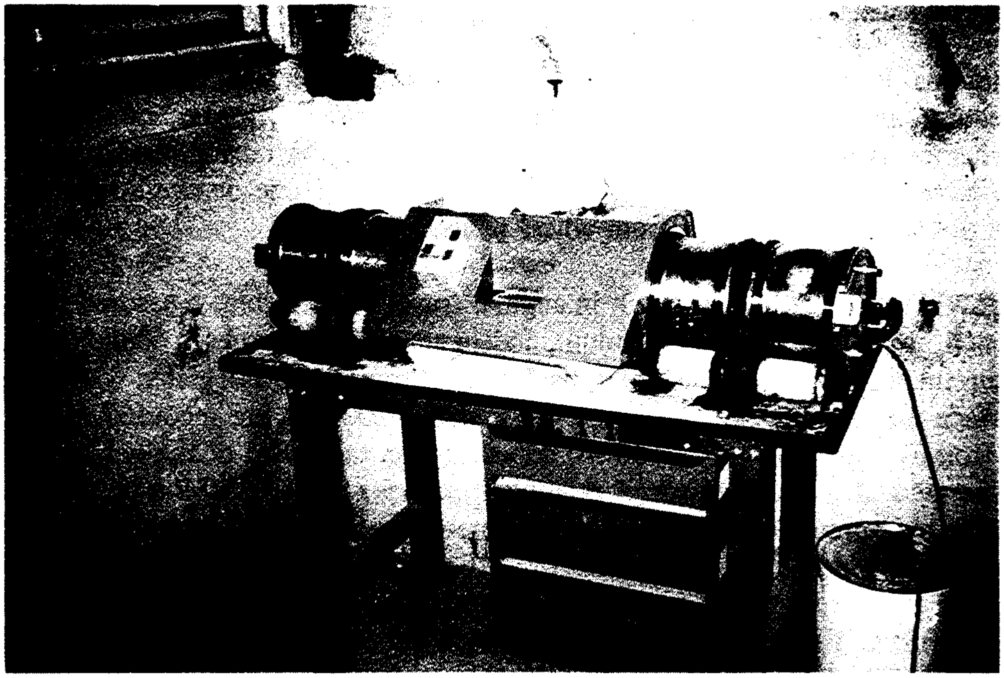

Figure 18.1. MLPC Micro-Deval Testing (MDE) Apparatus.

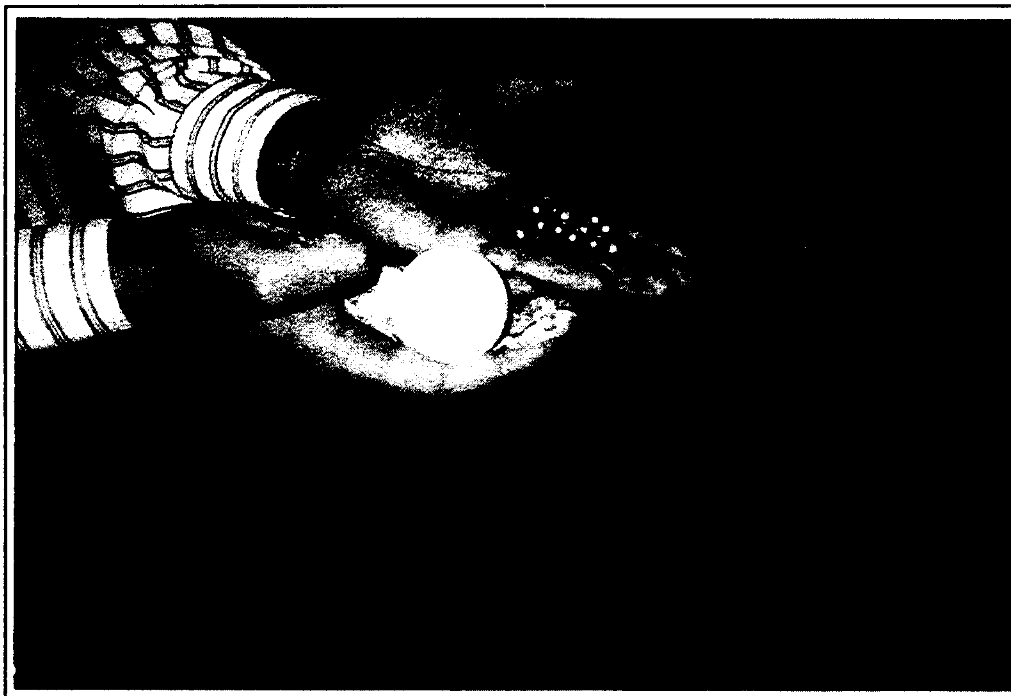

Figure 18.2. Comparison of Steel Ball used in LA Abrasion Test to Steel Balls Used in Micro-Deval Testing Apparatus.

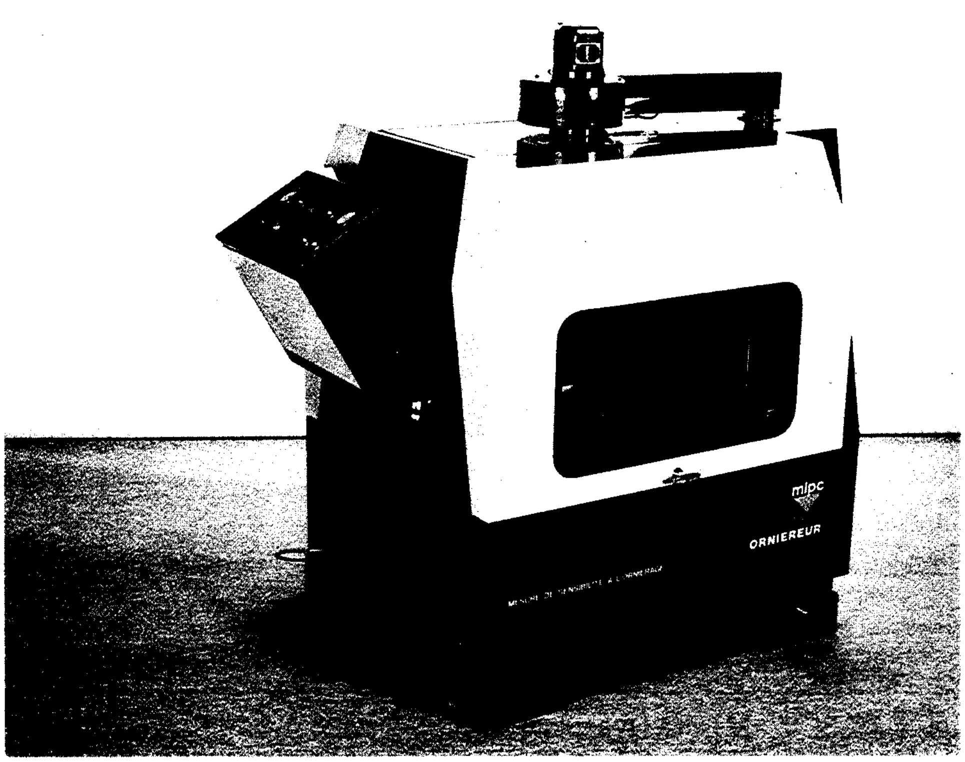

Figure 18.3. MLPC Pavement Rut Testing Device.

Figure 18.4. Contractor-owned MLPC Pavement Rut Tester.

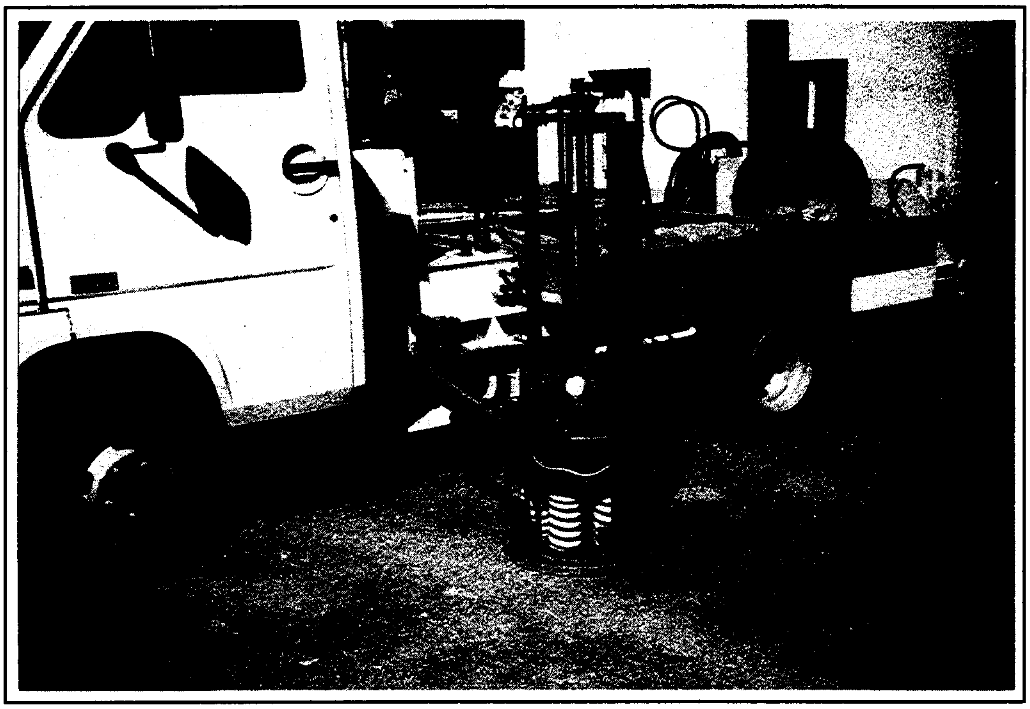

Figure 18.5. MLPC Dynaplate Testing Device.

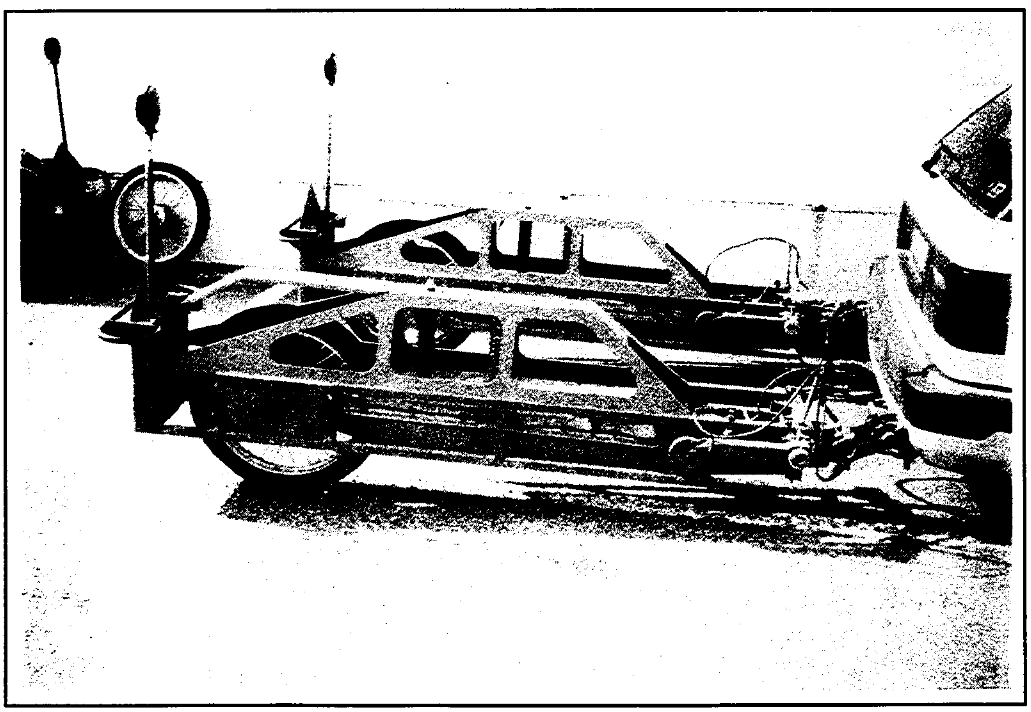

Figure 18.6. The Longitudinal Profile Analyzer (APL).

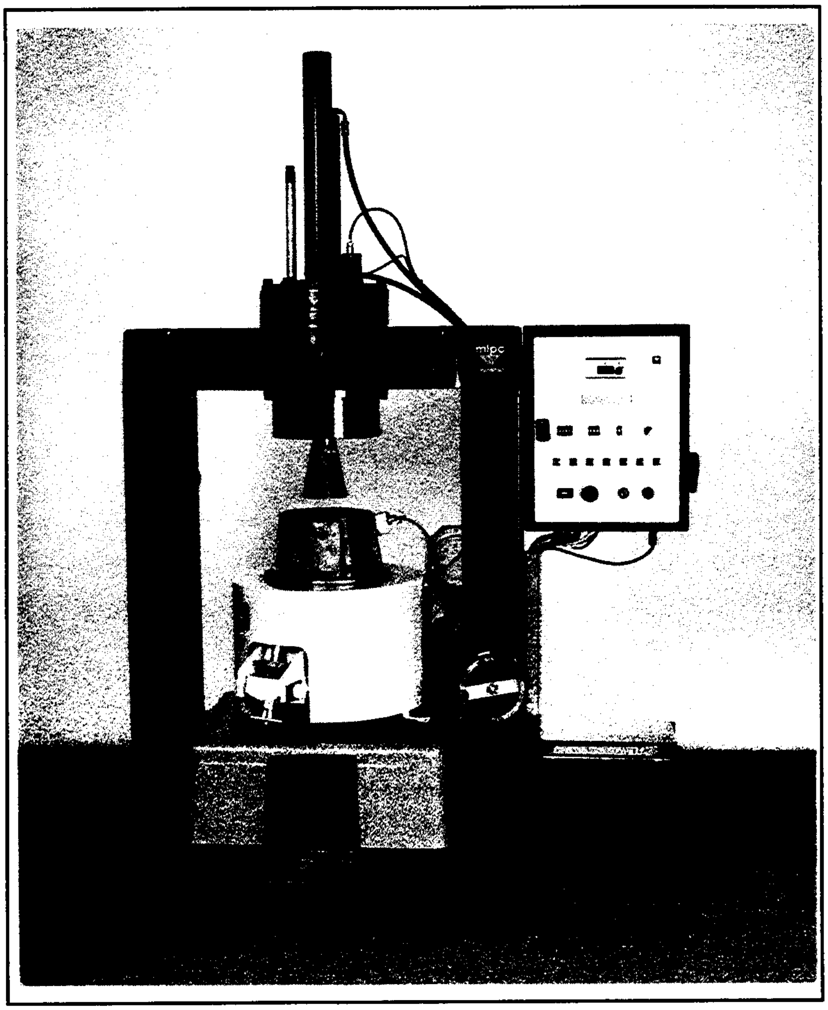

Figure 18.6. MLPC Gyratory Shear Compactor

XIX. Pavement Research Program

The LCPC is a world-class operation that conducts research on highway pavements and materials at their facilities in Paris and in Bouguenais (near Nantes). The LCPC in Paris is responsible for bituminous research. Three sections in Bouguenais handle pavement research-related matters in the areas of pavement design, pavement management, and pavement construction. The LRPC facilities assist in specific research activities with the LCPC. The pavement research program is categorized into several "Thèmes" or categories [71] comprised of the following:

CH-01	Microstructure, properties and durability of bitumens
CH-02	Chemical properties of polymer modified bitumens
CH-05	Measurement of pavement structures
CH-09	Methods of construction control of thickness, ride, and density
CH-10	Material uniformity, segregation, paving quality

In addition to the research undertaken by the Directorate of Routes, the LCPC performs research-related activities under contract to the major enterprises, materials suppliers, and other trade associations. This includes many of the research activities conducted at the LCPC fatigue test track in Bouguenais. Since 1984, the test track facility has simulated the passage of over 36 million trucks (or 35 times as many loadings as at the AASHO road test) in the course of over 60 experiments.

19.1 Experiment of Concrete Pavements at the Fatigue Test Track

The Directorate of Routes, sponsored by the concrete pavement contractors, and the lime and cement industries, undertook a major experiment at the LCPC fatigue test track, in order to review the soundness of the designs in the catalogues for concrete pavements. A paper on this project was prepared for the Fifth International Conference on Concrete Pavement in 1993 [72], and the final report is anticipated to be released shortly. Five types of concrete pavement structures were investigated, including dowelled and undowelled pavements, continuously reinforced concrete pavements (CRCP) and a variety of platforms including porous concrete.

19.2 Experiment of Elevated Modulus Asphalt Pavements at the Fatigue Test Track

This research effort was jointly undertaken by the LCPC, Société des Pétroles Shell, Scetauroute, and USAP to study the material characteristics of high modulus asphalts (EME) using the laboratory bending fatigue test with results obtained from the LCPC circular test track. The results, presented at the 1994 TRB Annual Meetings, indicated that strains calculated by the Alizé elastic-layered program using data from the bending fatigue test were generally higher than those measured at the circular test track. The calculated values using César, a finite element program developed by the LCPC, yielded values closer to the values measured at the circular test track than did the Alizé program. As an outcome of this study, the 1994 Scetauroute catalogue now includes an EME base. [73]

19.3. Porous Asphalt Materials

Experience has shown that porous asphalts clog and lose some of their benefits (noise reduction, drainage characteristics) in as little as one year. A research effort being undertaken by the LCPC is the feasibility of cleaning porous asphalts as well as other types of bituminous layers, using high-pressure water of between 15 and 25 MPa. Costs encountered for this process were reported to range from 3 to 6 F_r/m^2, or \$0.50 to \$1.00 per square meter [74]. This technique was reported on for the Pavement Technology Observatory meeting (discussed on page 59). [50]

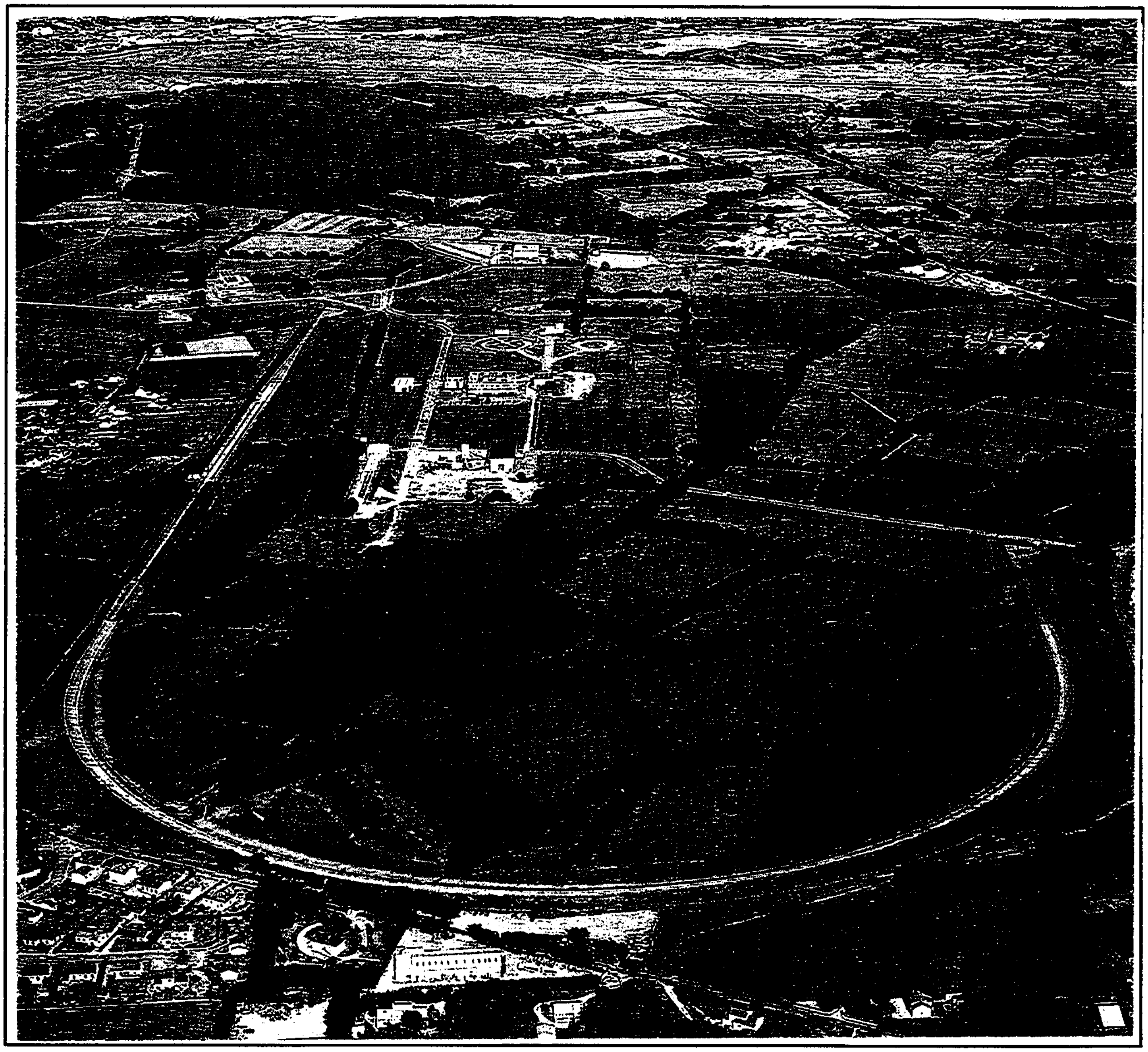

Figure 19.1. LCPC Facilities in Bouguenais, near Nantes. [22]

XX. International Conferences

Several international conferences and meetings in Europe were attended in 1993. Technical conferences in Europe are run in a format different from typical technical conferences in the United States, such as the Annual Transportation Research Board Meetings. In Europe, for each conference session, a Technical Moderator is responsible for performing (prior to the conference) a detailed review of all accepted papers on the session topic. This individual is then responsible for presenting the important highlights and summary of all accepted papers. Authors of accepted papers are generally present to respond to questions from the Technical Moderator and/or conference participants, and one author is sometimes requested to give a brief (e.g., five minute) overview of their paper. The Technical Moderator then concludes the session with an overall summary. This conference format is an effective means by which the important technical points or highlights are effectively and efficiently summarized for consideration by managers and administrators in attendance.

Listed below is a brief summary of technical conferences attended.

20.1. European Quality Enhancement Study Tour (Paris, France)

The Federal Highway Administration undertook in 1993 an in-depth review of contract administration techniques being used in European countries, including France. Members of the FHWA, State Highway Administrations, and industry participated in this Contract Administration and Quality Enhancement Tour (CATQEST) review. The objectives of CATQEST were to look at quality enhancement, and to assess the potential application of identified techniques to State highway programs, including contract award processes and quality control and quality assurance procedures. [3]

20.2. SHRP International Conference (The Hague, Netherlands)

The Europeans periodically host a SHRP International Conference in Europe. [75] These conferences are very well attended by representatives of the European highway community, providing a forum for the discussion of the latest activities in the SHRP program and the LTPP program. The Europeans have taken a very active role in evaluating SHRP products for their own use and benefit, and they have positioned themselves to be able to implement and use other SHRP products as they become available. Several European nations are also participants of the LTPP.

20.3. Eurobitume Congress (Stockholm, Sweden)

The mission of Eurobitume is to promote the efficient and effective use of refined bitumens in paving and other industrial applications. This congress was widely attended by representatives of the Directorate of Routes, contractors, and suppliers. [76]

20.4. National Maintenance Congress (Bordeaux, France)

The Directorate of Routes held their first national congress on maintenance in Bordeaux the fall of 1993. This congress consisted of several open forum discussions, and workshops open exclusively to Directorate of Routes employees. [77] Maintenance equipment, computer software, and other product displays were included in this congress. Much importance is placed on maintenance in France, and it was interesting to note that both their Minister of Public Works, Transportation, & Tourism and their Director of Routes (equivalent, respectively, to our Secretary of Transportation and our Federal Highway Administrator) opened this congress. News media were also present. The Director of Routes also spoke at the closing session. There were, in addition, representatives of highway departments from several other European and African countries that attended this congress.

20.5. National Concrete Pavement Conference (Braunschweig, Germany)

The German Annual Concrete Pavement Conference in Braunschweig was attended, in which topics pertaining to concrete pavement technology were discussed. German engineers had expressed an interest in the continuously (galvanized-strip) reinforced concrete pavements (CRCP-GS) built in France. This technique, which also impressed US TECH participants, [2] uses coiled steel strips furnished in diskettes, shortening construction work zones and minimizing impacts to traffic.

Presentations by the Directorate of Routes and the SAPRR at this meeting cited the short-term performance of these type pavements in France. Excessive transverse crack spacings has been encountered on sections of pavement constructed with 0.30 percent steel (from 1988 to 1991) and 0.34 percent steel (in 1992). Excessive crack spacings and excessive crack width openings can lead to steel rupturing and to development of punchouts and other long-term performance problems. Because of these concerns, the German BMV decided against constructing a CRCP-GS. Other papers have also been published which discuss the merits and shortcomings of this technique. [78, 79, 80]

A revised design of this system (a modified dimple on the galvanized strips and an increase in the percent steel to 0.40) has been under development. [78, 87] The use of 0.40 percent steel, with a modified dimple on the galvanized strips, was proposed for demonstration in Germany and/or Spain in 1994, but no project has yet to be constructed (in France or elsewhere) with the modified steel design. If ever constructed, the long-term performance of pavements built using this technique should be monitored, because of the potential benefits (including reduced construction time as well as minimizing impacts to the travelling public) which can be realized using this technique.

XXI. Site Visits to Other Countries- Germany

The Directorate of Routes coordinated and facilitated arrangements for attending the concrete pavement conference visit previously mentioned. The purpose of this visit was to gain a familiarity in some of the highway related activities underway in Germany.

21.1. General

The political structure of Germany resembles the United States much more so than does France. Unlike France (which has a strong central government), Germany is comprised of thirteen federal states. Each state is responsible for the highway program within their respective political jurisdiction, with funding aided through their federal ministry for transportation, or Bundesminister für Verkehr (BMV). The BMV functions both as an oversight agency and as a technological service agency. For example, the BMV approves decisions (contract awards) for federal projects over 5 million Deutsche Marks (DM), or $3 million.

Germany has an extensive network of Autobahns; all of these routes are non-toll. Most of these pavements (with the exception of pavements located in the four eastern states, which were reunified into their federal republic only four years ago) are in very good condition. Because of reunification, many engineers indicated that funding to reconstruct older pavements is less available than in the past; funding has been dedicated to reconstructing or cracking & seating and resurfacing the Autobahn system in the new states. Several engineers expressed an interest in concrete pavement rehabilitation and overlay techniques, including the saw & seal technique for use with asphalt overlays.

Discussions with BMV representatives revealed that the Germans were looking at alternate funding sources for their Autobahns. Because of the numerous interchanges, introducing toll booths would be unpracticable. Other methods were also being considered, including a system similar to that used in Switzerland. Any vehicle that uses the Autobahn/Autoroute/Autostrada in Switzerland, even for one day, must visibly display a vehicle sticker sold for 30 Swiss Francs, or $20.

21.2. Research Center

The Bundesanstalt für Straßenwesen (BAST) is the German national road research center located in Bergisch-Gladbach, near Cologne. This facility provides technical services and advise to their federal republic and to their states, develops specifications, and performs other research and development studies. Approximately 400 individuals (including 120 technical specialists) are employed at this facility. The annual budget for this facility is approximately DM 50 million, or $30 million.

21.3 Pavement Design

The Germans use catalogues for pavement design.[81] Contractors are allowed to propose alternative pavement designs. These alternative designs are equivalent (based on the design catalogue traffic levels and subgrade support) to the design included in the original contract document. Reductions in layer thicknesses for innovative materials are not allowed. Prices for alternate designs are negotiated after contracts have been awarded but before work commences.

21.4. Pavement Construction and Rehabilitation

Active concrete pavement projects were visited east of Berlin on the A-12 autobahn with a resident engineer from the State of Brandenburg. One project consisted of construction of a 3.5 km long jointed plain dowelled concrete pavement. The pavement structure built was 270 mm thick over a drainable fabric layer over 150 mm of a cement treated base over 300 mm of crushed PCC removed from the existing alignment. A Gomaco Paver was being used to construct this pavement.

Another project on the A-12 autobahn was visited that consisted of cracking & seating a concrete pavement constructed over 60 years ago. Cracks were induced at 1.5 m spacing, and their ten year design consisted of 40 mm of a surface course, 40 mm of binder material, a sami-interlayer, 40 mm of binder material, and 60 mm of a levelling course over the cracked pavement. No work was underway on the day of this visit.

21.5. Pavement Condition

Travelling from Berlin to Cologne via Dresden on the A-13 and A-4 autobahns was specifically undertaken to observe the condition of in-service concrete pavements. These rigid pavements, which were constructed approximately 60 years ago, had received virtually no maintenance for 50 years. Because of the poor condition of the A-13 autobahn (faulting of 10 to 30 mm typically encountered at transverse joints and cracks, shoulders in a hazardous condition), travel was limited to 80 km/h or less. These pavements dramatically demonstrate the consequence of neglected maintenance (although heavy truck traffic was also virtually absent until 1989). Figures 21.1 and 21.2 illustrates a typical pavement on the A-13 autobahn.

Virtually all of the Autobahn from Dresden west to Cologne on the A-4 autobahn is in the process of being resurfaced or appears to have been resurfaced during the past four years. A high priority has been placed on reconstruction and/or heavy resurfacing of all of the autobahns in eastern Germany. Consequently, heavy maintenance activities (versus reconstruction) and short-term repairs have become more prevalent on autobahns in western Germany, as funding for highways in the western part of Germany has become more limited.

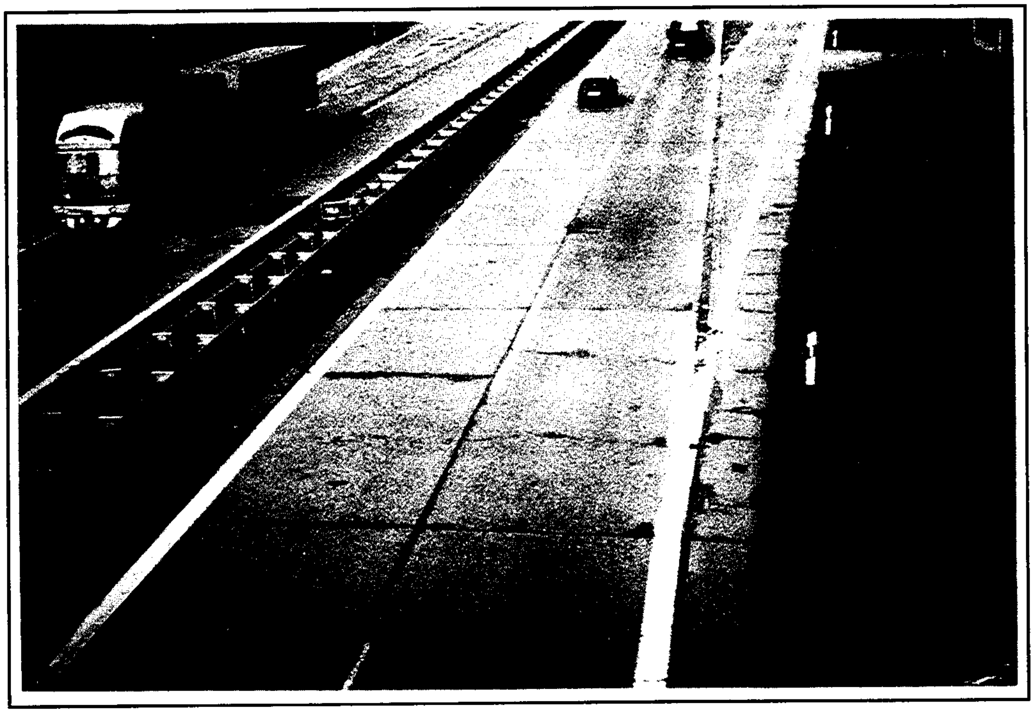

Figure 21.1. The A-13 autobahn in the German State of Brandenburg.

Figure 21.2. Mid-panel cracking and faulting, typical distresses encountered on the A-13 autobahn in Germany.

Figure 21.3. Bituminous surface maintenance, the A-6 autobahn, east of Saarbrücken, Germany.

XXII. Impressions

This section of the report includes a conglomeration of topics, related to transportation, to give the reader an added appreciation of some of the nuances of the environment under which the European highway community operates.

22.1. Society

Europeans live in a society not as disposable as ours. Glorious cathedrals, imposing castles, and simple homes for the common man have stood generations. Most residences, as well as many other buildings, are built out of stone or concrete; wooden frame structures in sprawling new communities are rarely found. In most aspects pertaining to the infrastructure, conservatism is apparent in the design process.

The non-disposable mind-frame exists in the design of pavement structures as well. Although the surface layers receive continuous attention (through resurfacing or recycling), underlying base courses are generally much thicker than those in the United States, since the base layers are intended to last many years. The subbase or platform layer on which pavements rest (shown in Figure 22.1) are generally intended to function for 30 or more years. In addition, for example, the base layer(s) under some of the Autobahns in central Europe, originally built in the 1930's, still serve motorists on the original alignment, although the geometrics are obviously not as desirable as those for newer facilities.

22.2 Unique Transportation Demands

Europeans generally take four to six week vacations, a benefit still enjoyed by even the newest of the employed. In France, a large segment of the population takes vacation during the month of August, and Paris becomes a virtually deserted city, with many shops and restaurants being closed for the month. This puts a tremendous demand on the transportation system during the first and last weekends of the month (11 million vehicles on the road out of 23 million vehicle in the entire country), when the masses flock to the coasts, the mountains, or to other destinations in Europe and abroad. [82]

22.3. The Road User

It has been said that Europe is a continent of aspiring race-car drivers. The speed limits on the Autoroutes in France is 130 km/h in dry weather, 110 km/h when raining (see Figure 22.2). Facilities on the other limited access facilities are posted at 110 km/h. However, enforcement of speed limits is sparse; the French have a disdain for speed limits. Slower drivers using the inside lane(s) literally risk getting run off the road, especially if they are driving at the speed limit. It is common practice all across Europe for faster drivers to flash headlights in order to let slower drivers know that they need to move over to the outside lane. It is illegal to pass a vehicle from the right, a law faithfully observed by virtually all drivers.

Posted speed limits on the German Autobahns is a 130 km/h, however this is only a suggested limit. Vehicles sometimes travel at 170 km/h or more. Because of the higher speeds and higher traffic volumes (in part because of no tolls), driving in Germany was much more intensive than in France. It was remarked that German politicians who propose strict enforcement of the (now voluntary) 130 km/h speed limit face the fate of being routinely voted out of office.

22.4. The European Network

The European Agreement on Main International Traffic Arteries, enacted in 1983, provides a plan for a European international network of highways. This network, far from consistent, includes both two lane rural connectors as well as the controlled access facilities. This network consists of a grid system of routes, even numbers generally running east-west starting from the north, odd numbers generally running north-south starting from the west. These routes are designated with "E" numbers, and the convention for signing these routes varies from country to country, although most countries include both their own route number with the European route number. [83]

22.5. Highway Signing

Travelling in Europe by car is an interesting experience. Signing of many destinations, including train stations and tourist attractions, within the major cities of France, is excellent. In Paris, for example, there are a number of directional signs at virtually every major intersection which guide tourists to key destination points in the city.

However, following a numbered route in, through, or out of most cities in Europe is frustrating if not impossible. The consistency of route signing leaves much to be desired, and there are rarely, if ever, advanced route numbers encountered when approaching National or Departmental routes, even on the Autoroutes. Most routes are only marked by destination, and it was always necessary to refer to the Michelin map and to remember the key towns located in the proximity of the town to which one was driving. Nowhere in Europe were routes found to be designated by cardinal direction (i.e., north, south, east, or west). Because there is no consistency in route numbering in Europe, the internationally recognized Autoroute sign is used throughout Europe to inform motorists that a particular facility is a limited access facility.

22.6. Safety

Safety seems to be a feature not predominately incorporated into design features of highway facilities. Our Interstate System, safest in the world, includes gradual side slopes, clear zones, wide grassed medians, inside shoulders, rumble strips, and other auxiliary features to enhance safety. Drop-offs of 0.4 m or more immediately adjacent to the shoulder of high speed facilities are not uncommon in France (see Figures 22.4 on 22.5). Inside paved shoulders exceeding 0.5 m are rarely encountered; most high speed facilities, even in rural areas, are constructed in narrow right-of-way separated by a concrete barrier or guardrail, and not 20 m wide medians.

The fatality rate in France on their highways is approximately twice what it is in the United States. [84]

22.7. Traffic Control

Traffic control in work zones is not uniform across the EU, and sometimes not even across Departmental lines. In urban settings, passing lanes are sometimes squeezed down to widths of 2 m or less.

Lane markings throughout Europe vary. For example, France and Germany use white lane markings everywhere, with the exception of yellow markings which are used in construction zones. Switzerland uses orange pavement markings in construction zones. Pavement markings in Austria are white and yellow, although where and how they are used varies between each of their federal states. When lane shifts are necessary (see Figure 22.6) because of construction operations, old lane markings are rarely removed or obfuscated. Reflective pavement markers are not used extensively in Europe, making nighttime driving, especially in wet weather conditions, very difficult.

22.8. Motorist Services

Most high speed limited access facilities in France are toll facilities, consequently every 50 km on the Autoroutes there is an oasis which include a service station, a restaurant, a playground, and sometimes even an ice-cream shop or a motel. These type facilities are encountered even along their non-toll limited access Autoroute and LACRA facilities, which may contribute to the maintaining of a rural character along many of their highways and to a lack of urban sprawl.

Because services are provided along the Autoroutes, specific service signs are not encountered when approaching interchanges. The only exception is the specific service sign encountered at the main entry points to each Autoroute, and this sign displays the brands of fuel, prices, and distances to each oasis along the Autoroute, as shown in Figure 22.7.

22.9. Rotary Intersections

Approach roads to many limited access facilities in rural/suburban areas are constructed using rotary intersections in lieu of signals or stop signs on each side of the limited access facility. In some cases, only one rotary is superimposed directly over the limited access facility, necessitating the need for an additional structure (see Figure 22.8). [85] Functionally, these intersections appear to work very well in rural/suburban settings with low to moderate volumes of traffic.

There are communities in France which have recently rediscovered the rotary intersection. For example, the city of Nantes (population 200,000) is replacing a significant number of signalized intersections with rotary intersections. Sometimes, one intersection was replaced with two rotaries placed tangent to each other. The operation of many of these intersections, squeezed into the urban setting with a very tight radius, is less than desirable.

22.10. Art and Esthetics

Expressions of art can be found along many routes in France, as well as in the middle of the many rotary intersections. In some cases, artifacts are placed on the side-slopes within the clear-zone of the mainline autoroutes. For example, large balls, squares, triangles, and other artifacts were encountered in the clear zone along several kilometers of the A-4 autoroute in Champagne-Ardenne. Figure 22.9 illustrates one example encountered at a new rest-area facility south of Paris.

Noise walls, especially in urban settings, often include a variety of colors, materials, and textures which either blend or dramatically contrast with the urban setting. The noise attenuation walls on the newer autoroutes (e.g., the Lyon bypass) were very pleasing in appearance.

Figure 22.1. Granular platform layer for an autoroute pavement.

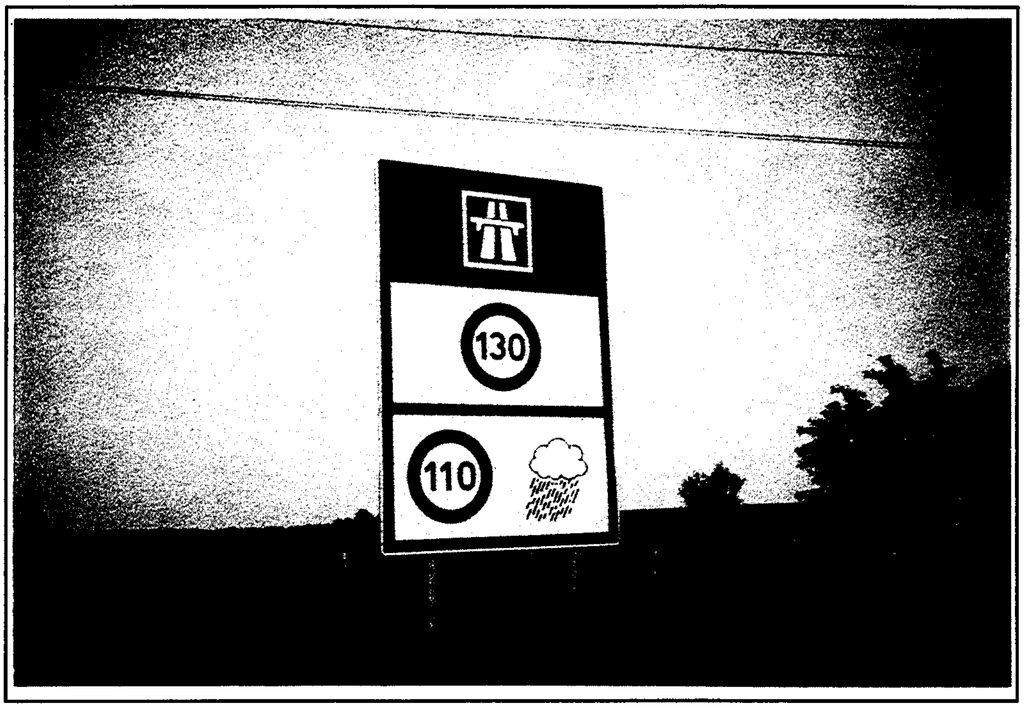

Figure 22.2. Autoroute speed limits in dry and wet conditions.

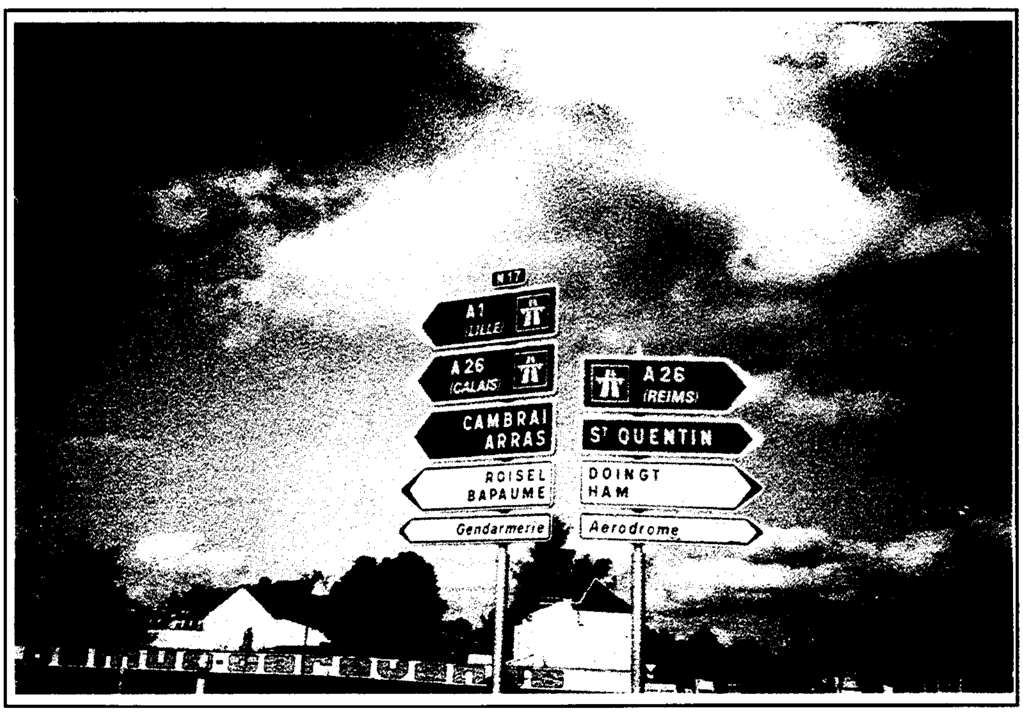

Figure 22.3. Typical guide signs at intersection adjacent to autoroute.

Figure 22.4. Steep dropoff adjacent to mainline autoroute.

Figure 22.5. Paved concrete ditch adjacent to autoroute pavement.

Figure 22.6. Permanent and temporary lane markings on autobahn.

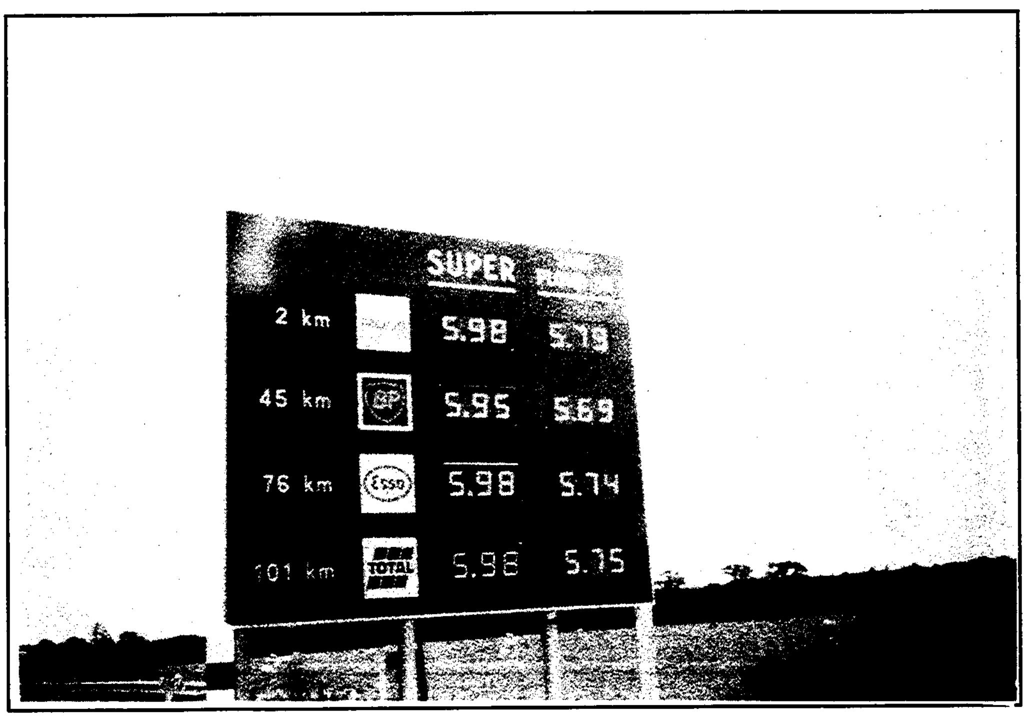

Figure 22.7. Advisory signs indicating distances to service stations.

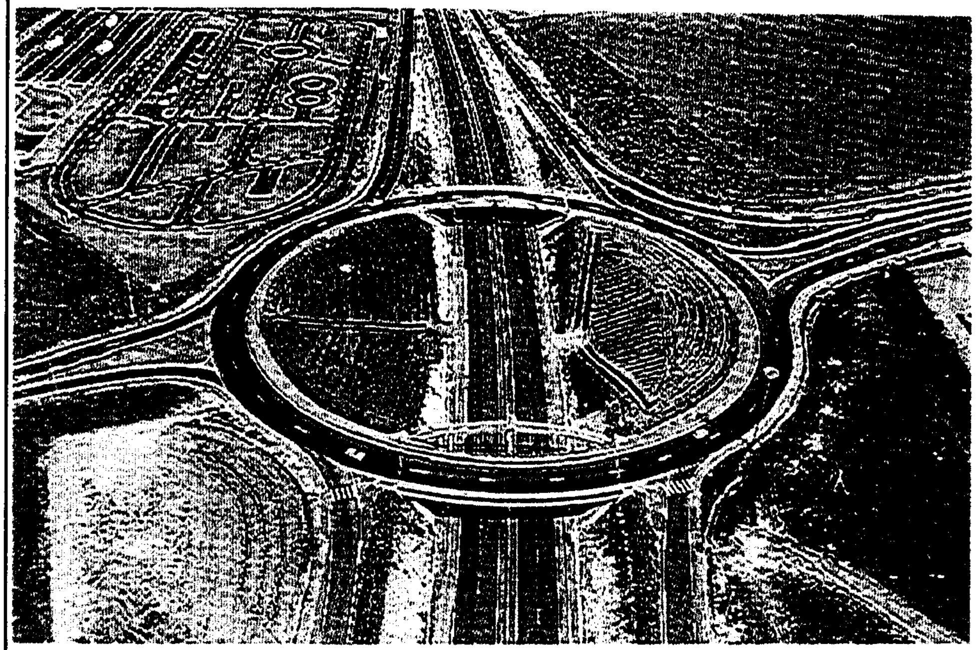

Figure 22.8. Rotary interchange superimposed over autoroute. [85]

Figure 22.9. Artifacts placed along ramp leading to rest-area.

XXIII. Recommendations

Recommendations developed as a result of this assignment, which echo those developed during the EAST [1], US TECH [2] and CATQEST [3] tours, include the following items which have the *potential* for improving the quality of our highways and our stewardship of the National Highway System:

23.1. Administrative Recommendations

- Establishing, at the national and/or regional level, a focal point for collecting and disseminating information about developments in pavement technology to the public and private sector. The US TECH report specifically cites such a need, stating that it could be based upon continuing SHRP efforts, including a broad-based advisory board. [2] Another step towards accomplishing this recommendation is, perhaps, through the eventual establishment of national/regional technical services centers functioning under the umbrella of the FHWA. Such centers have effectively served the highway communities in European countries, providing broad-based technical knowledge and expertise to a well-trained staff of generalist engineers.

- Establishing, at a national and/or regional level, a network of well connected research and development laboratories to serve as the backbone of regional/national research and development activities. The well connected network of research and development laboratories in Europe impressed the EAST participants, who recommended the development of a consortium of highway research laboratories, both public and private, as a necessary step towards efficiently utilizing research dollars by minimizing duplicative research efforts. [1] This could also be accomplished under the umbrella of either the FHWA or the Transportation Research Board.

- Continue fostering partnerships and exchanges between engineers from our country and engineers from abroad. The positive experiences of highway departments in other nations should be tapped into, utilizing their research and development accomplishments and efforts to promote practices and procedures which may improve the quality of our pavements. Many technical issues transcend political boundaries, and a major factor why the Europeans are able to use our technology to their advantage is simply because they understand our english language documents. One immediate stride which could be accomplished to close this one-way exchange of knowledge is to develop a clearinghouse for collecting, translating, and distributing selected documents, research reports, catalogues, and other technical work, as suggested in the US TECH report [2], for use in our highway community.

23.2 Process and Product Recommendations

- Evaluate selected MLPC devices in research related activities, to ascertain whether utilizing these devices can improve the quality of our pavements. For example, the procedures for testing mixes, including the use of the rut tester equipment, may be used to reduce plastic rutting in flexible pavements; the micro-deval device may improve the quality of aggregates for special uses. In addition, monitor the standards being developed and adopted by the European Committee for Standardization (CEN). We should maintain an understanding of the background behind CEN standards to be able to address whether the selective use of their standards and/or testing procedures may have a positive impact on quality.

- Evaluate innovative contracting procedures including the use of alternate bids; Although not a panacea, a *well-established* procedure could allow for innovation by the private sector without compromising the merits of the competitive bid process. This was also recommended in the CATQEST Report[3]. Well established procedures (e.g., accelerated testing, laboratory fatigue testing) could also allow for the use of proprietary products.

- Facilitating the use of innovative asphalt mixes into the design procedures for flexible pavements. Although pavement thicknesses have historically been empirically based (i.e., using a structural coefficient of 0.44 for asphalt concrete), with the completion of the SHRP and the development of SUPERPAVE, laboratory work can be performed on binder and mixture materials and mechanistic properties determined to predict performance under predicted loadings. Long-term field evaluation efforts would be continued to monitor the true performance of these innovative mixes and to calibrate the design procedures accordingly.

- The National Cooperative Highway Research Program (NCHRP) has a study underway to examine the viability of developing a national catalogue using the AASHTO design procedures.[86] Because of the variety of materials and climatic conditions encountered across the United States, it is difficult to envision the development of a design catalogue useable for the entire country. The development of a design catalogue for one highway department (with perhaps 15 to 20 pavement types) may be a more practicable solution.

  Based on observations of how design catalogues were being used in France (several catalogues, many variations on layer thicknesses based on local conditions or other factors), it appears the greatest advantage in the formulation and use of design catalogues is that it includes good design practices (e.g., drainage layers, crack relief layers, widened lanes, positive load transfer devices) which may be overlooked by an inexperienced designer. The selection of appropriate layer thicknesses is, of course, facilitated by the use of design catalogues.

- Continually reevaluate the priority placed on routine maintenance on our National Highway System. Because of national demographics (as shown in Table 1.1), there are, on average, five times as many kilometers of major or national type highways per person in the United States than there are highways per person in France. Phrased another way, each person in the United States is responsible for financing the maintenance of five times as many kilometers of highway than is the average person in France.

  In the past, catastrophic bridge failures in the United States were addressed by the creation of specific funding targeting bridge replacement. Catastrophic pavement failures in France in the 1960's resulted in aggressive actions being taken to repair and maintain their network of highways. Non-existent highway maintenance for 50 years in the eastern states of Germany provided a wake-up call to engineers and highway users on the consequences of neglected maintenance. Neglected or postponed maintenance has certainly contributed to the slow deterioration of some of our highways, but the lack of catastrophic failures does not lead to a potential sense of urgency which may be needed in maintaining the existing infrastructure entrusted to us.

  Consideration could be given to the development of maintenance catalogues, to facilitate the incorporation of good maintenance practices on the proposed National Highway System.

- Specific geometric design techniques which should be considered include the use of trapezoidal cross-sections for pavement structures; these have been effectively used on pavements in France and elsewhere in Europe. The use of 2.5 percent base cross-slopes and 2.0 percent surface cross-slopes results in a thicker pavement structure along the outer edge of the pavement, where a higher percentage of trucks induce heavier loadings on pavements. In addition, subsurface drainage characteristics are apparently improved.

- Continuously reinforced concrete pavements using galvanized strips (CRCP-GS) impressed US TECH participants.[2] This technique uses coiled steel strips furnished in diskettes, shortening construction work zones and minimizing impacts to traffic. When using 0.30 percent steel (as was done from 1988 to 1991) and 0.34 percent steel (in 1992), excessive crack spacings were encountered. Excessive crack spacings result in excessive crack width openings, which result in possible rupturing of the reinforcing steel and other long-term performance problems. A revised design (increasing the amount of steel as well as modifying the dimple on the galvanized strips) has been under development.[78, 87]

  CRCP-GS using the revised design has yet to be demonstrated on an in-service pavement. If constructed (in France or elsewhere), it is recommended that the construction and long-term performance of these pavements be monitored, to assess whether it is beneficial and cost-effective to pursue demonstrating this technique in the United States. The potential benefits of this technique mirror fast track concreting procedures (i.e., minimizing impacts to traffic) which have been used successfully in several states.

- Consider utilizing the moderator format typical used for technical conferences in Europe. This format is an effective means by which important issues pertaining to detailed technical topics are summarized for consideration by higher level managers and administrators. Using this format, a well-respected Technical Moderator is responsible for reviewing papers, for presenting the important highlights and summary of all pertinent papers, and for providing a brief conclusion of the session with an overall summary.

23.4. Closure

Several years ago, the Directorate of Routes detailed an individual to learn about the highway program in the United States under a two-year assignment. Paraphrased is an excerpt from a report developed summarizing observations made as a result of that assignment:

> It is irrelevant to compare the state of the technology in a foreign country to one's own. It is rare that observations developed during an international assignment provide solutions suitable for all; the scope of problems in other countries are never, in general, identical. The outcomes from this assignment do not escape this rule. Much work will be required, sorting, analyzing, digesting, etc., so that, little by little, this work will develop into implemented solutions for addressing the problems we face. [88]

Echoing those remarks, much work remains. We must continue to seek out opportunities for improving the way in which we conduct our business. We must continuously work, as stewards of our proposed National Highway System, to better the condition of our nation's pavements.

XXIV. References

The references as listed indicate the language of the text. References including both English and French titles indicates that the substantial portion of the text includes both languages. English translations of French documents are also denoted where available.

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